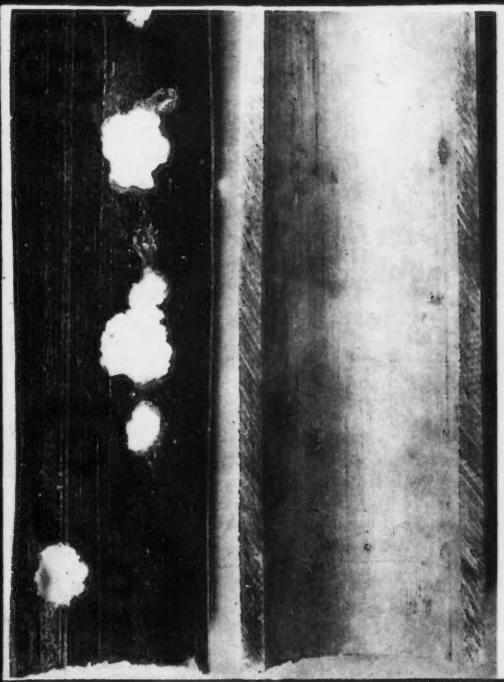
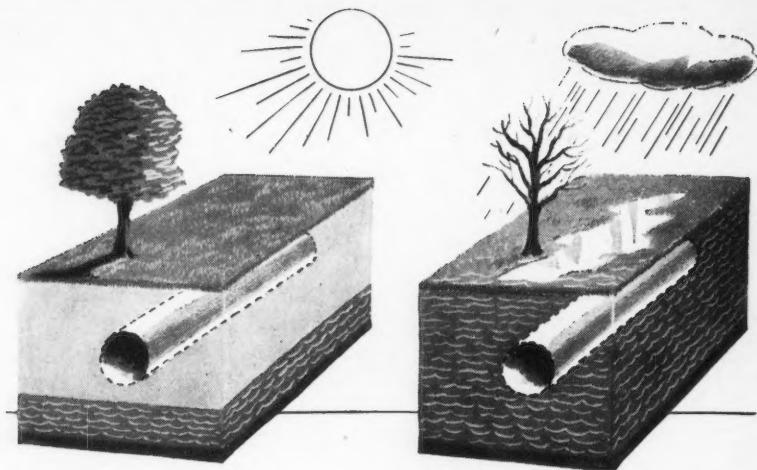


Corrosion





Stability of Electrical Resistance of Coal-tar Enamel an important factor in **THE ECONOMICS OF CATHODIC PROTECTION**

Corrosion-proof pipelines demand the use of stable electrical insulation—Coal-tar Enamels—to permit the economical use of Cathodic Protection.

Coal-tar Enamels, because of their ability to resist moisture absorption, provide constant, uniform and long-lasting STABLE insulation. They are not affected by the changing moisture content of soils, due to variation of seasons and weather conditions.

Pipelines—efficiently protected with Coal-tar Enamels—do not require a robot, or any especially designed equipment, to vary automatically the amount

of electrical current required with the change in moisture content of soils, to make Cathodic Protection function properly.

Stability of Electrical Resistance of Coal-tar Enamels saves money and helps to reduce the cost of installing Cathodic Protection equipment. Barrett Coal-tar Enamels have demonstrated their effectiveness through years of service in all types of soils and climatic conditions. Applied by modern methods in the field or mills, and electrically inspected, they are your assurance of sound economy.

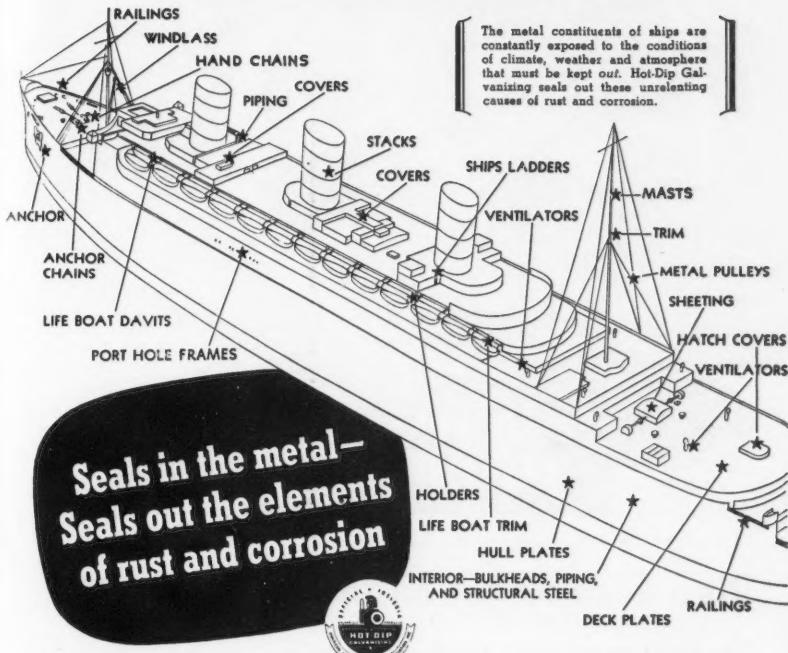
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ALLIED CHEMICAL & DYE CORPORATION
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For the utmost in Rust Prevention



Seals in the metal—
Seals out the elements
of rust and corrosion



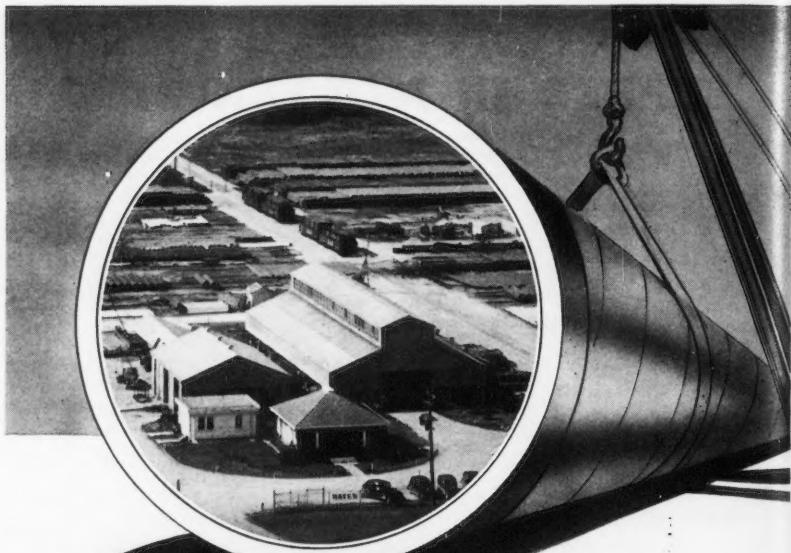
ONLY the Hot-Dip method of Galvanizing provides a bond of iron-rich alloy between base metal and its protective zinc coating. This bond firmly holds the protective layer of zinc, sealing in the metal, sealing out the elements that are the cause of rust and corrosion.

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Galvanizing as practiced by the members of the American Hot Dip Galvanizers Association does provide the utmost in lasting protection against the ravages of rust and corrosion.

For information on your problems of rust and corrosion, write American Hot Dip Galvanizers Association, Inc., First National Bank Building, Pittsburgh 22, Pa.

For the best Zinc Coating
use **hot-dip** **GALVANIZING**



"PUTTING
Permanence
IN PIPE"

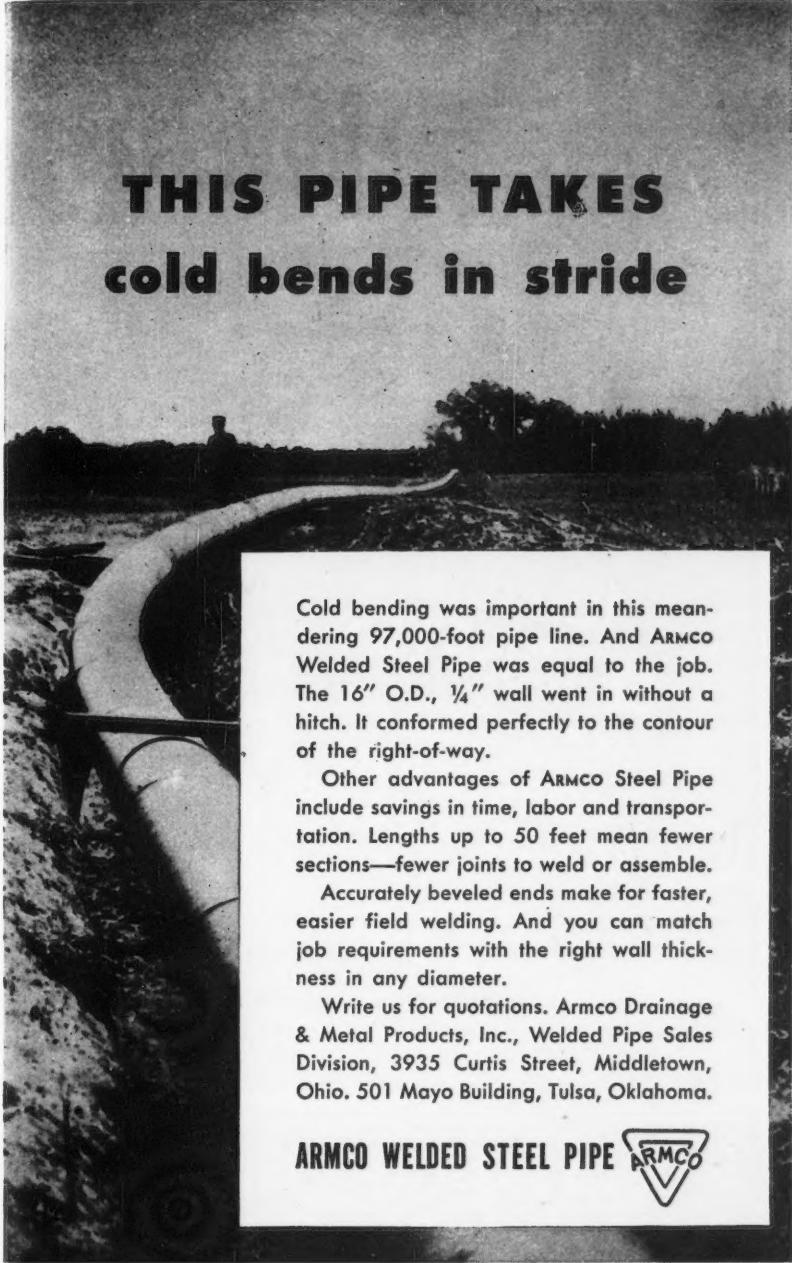
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HOUSTON, TEXAS



THIS PIPE TAKES cold bends in stride

Cold bending was important in this meandering 97,000-foot pipe line. And ARMCO Welded Steel Pipe was equal to the job. The 16" O.D., $\frac{1}{4}$ " wall went in without a hitch. It conformed perfectly to the contour of the right-of-way.

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Accurately beveled ends make for faster, easier field welding. And you can match job requirements with the right wall thickness in any diameter.

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WATER PROBLEMS

**HAERING
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over a period of years
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**CORROSION,
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WATER



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Reilly Protective Coatings

A black and white photograph showing a large industrial pipe line filter system. The top part of the image shows a horizontal pipe with several circular filter cartridges attached by clamp rings. Below this, a large cylindrical filter cartridge lies horizontally, showing its length and the mesh of the filter material. The background is dark and textured.

ALCO Pipe Line Filters*

**Installed on many product pipe lines
...ALCO Clamp Ring basic operating
advantage**

Development of the ALCO Clamp Ring opened the way to important improvements in pipe line filter design. Because it permitted the full cross-sectional area of the shell to be useful, ALCO engineers were enabled to design a filter in which a separate, easily removable filter basket could be centrally located in the shell. Because the filter basket could be so located, the space between it and the shell is available for proper dispersal of the incoming product over the filter surface. Because the filter basket is readily removable, the filter medium can be quickly and easily discharged and renewed.

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developed a special filter cartridge of assured uniform density. These efficient, easy-to-handle cartridges eliminate the nuisance of handling, shredding and packing baled filtering material. ALCO supplies a special device for loading and unloading these cartridges.

ALCO Pipe Line Filters Installed on "Little Big Inch," "Canol," and other pipe lines

ALCO Pipe Line Filters are on the "Little Big Inch" (Baytown, Texas, to Bayonne, N. J.), the Canol Pipe Line (Fort Norman to Whitehorse, Canada) and others. Hundreds of these ALCO units are in service. Protect your pumps. Reduce maintenance costs. Use ALCO Pipe Line Filters to eliminate gritty material. Complete description and schematic drawings show design and operation in *ALCO Bulletin 1033*. Copy sent promptly on request.

*Patent Pending

American Locomotive

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30 Church Street, New York 8, N. Y., Dunkirk, N. Y.

Magnesium Anodes for Cathodic Protection

New light on the control of galvanic corrosion has developed from work now in progress at Dow on the use of magnesium anodes for cathodic protection.

The Dow research program to date covers a long series of laboratory and field tests and has produced some very interesting data. As rapidly as this information can be prepared for publication, it will be made available.

Tests on pipe lines, steel foundations, underground tanks, and metals in contact with sea water indicate that galvanic corrosion can be materially reduced by the use of expendable external anodes of magnesium. Because of its high electrochemical

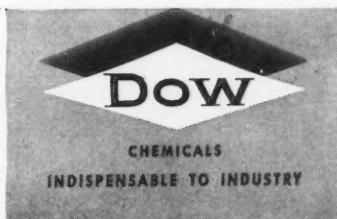
equivalent and its high driving voltage, magnesium is a logical material for this purpose.

Replaceable magnesium anodes, connected to structures to be protected, show marked effectiveness in supplying the current demanded by cathodic areas, correspondingly reducing the rate at which anodic areas on the structures are dissolved.

Results to date indicate the potential usefulness of magnesium anodes in the practical control of galvanic corrosion on an industrial scale. Dow invites industrial concerns and individuals confronted with corrosion problems to contact the nearest Dow office for literature or consultation.

MAGNESIUM DIVISION
THE DOW CHEMICAL COMPANY
MIDLAND, MICHIGAN

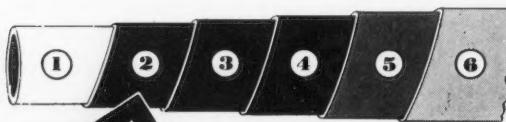
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Easy as A-B-SEE!

To simplify ordering pipe coating and wrapping, Pipe Line Service Corporation offers you the easiest specifications you could ask for. You indicate either "Specification A" or "Specification B" together with the coating material desired and PLS does the rest. When you consider that you can get any type of protection you want, it's just good business to let Pipe Line Service assume the complete responsibility for the finished job.



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- (4) Hot application of desired coating.
- (5) One spiral wrapping of desired wrapping material.
- (6) One spiral wrapping of heavy kraft paper.



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- * (2) Mechanical priming with desired primer.
- (3) Hot application of desired coating.
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**PROTECTIVE COATING
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*Primer not required with
No-Ox-Id coatings.

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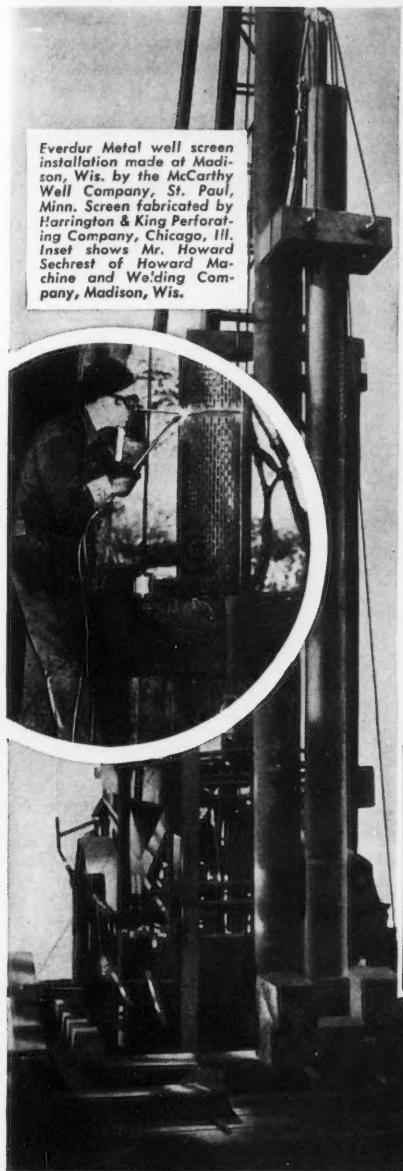
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270-Ft. EVERDUR Screen

puts new life
into Old Well . . .

Everdur Metal well screen installation made at Madison, Wis., by the McCarthy Well Company, St. Paul, Minn. Screen fabricated by Harrington & King Perforating Company, Chicago, Ill. Installed by Mr. Howard Sechrist of Howard Machine and Welding Company, Madison, Wis.



BECAUSE of repeated cave-ins, one of the wells operated by the Water Department of the city of Madison, Wisconsin, had to be taken out of service. Service was restored by installation of a well screen of Everdur* Metal.

States Mr. L. A. Smith, Superintendent, "It was clear that the life of the well would be dependent upon the life of the screen. The material finally selected was Everdur Metal, the life of which was estimated to be at least 25 years."

The accompanying photographs show installation of the Everdur screen . . . 20 lengths totaling 270', 12" dia., $\frac{1}{8}$ " thick with slots $1\frac{1}{2}$ " long x $3/16$ " wide.

For waterworks and sewage treatment equipment Everdur Copper-Silicon Alloys have proved to be highly versatile. Combining the corrosion resistance of copper with high strength and weldability, they make possible lightweight construction, assure long, economical service.

For detailed information write for Publications E-11 and E-6.

*Reg. U. S. Pat. Off.

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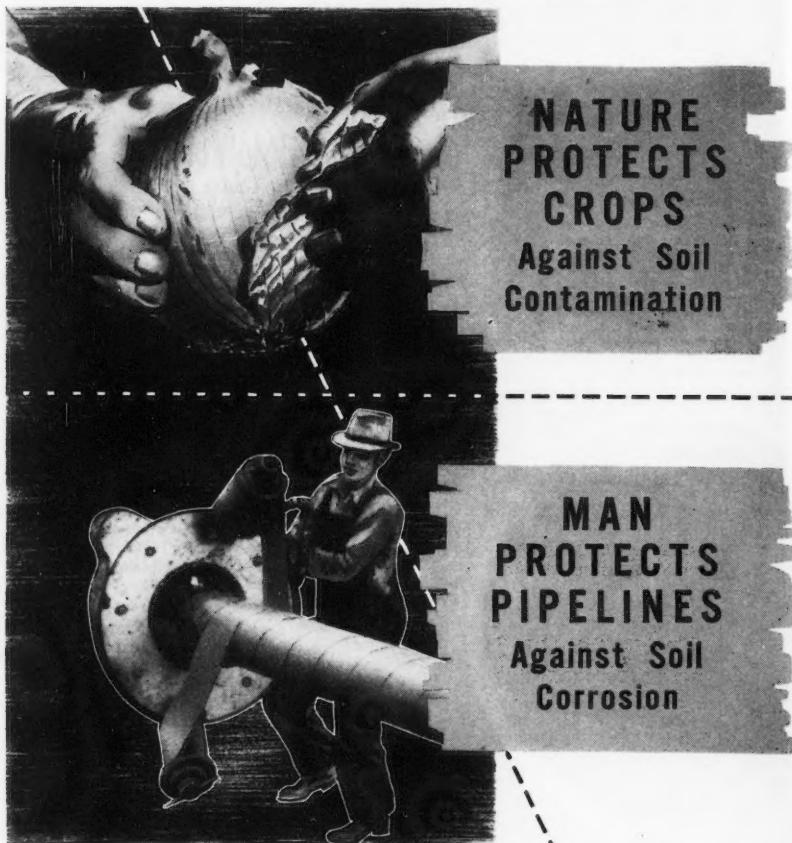


Everdur

COPPER-SILICON ALLOYS
THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut
Subsidiary of Anacoda Copper Mining Co.
In Canada: Anacoda American Brass Ltd.,
New Toronto, Ont.





Nature develops protective coatings for her products. The humble onion is an example. As the onion bulb is maturing, the upper part of the "scales", or leaves, dry, shrivel, and twist tightly together.

Inner portions are thus protected from shearing action of the soil, from discoloration, from moisture.

Man also uses similar protective methods by applying NO-OX-IDized wrapper, which envelopes pipelines laid through highly corrosive soils. Used with NO-OX-ID, the original rust preventive compound, NO-OX-IDized wrapper resists soil action, reinforces the coating, and bars corrosion. Write for details.



The ORIGINAL RUST PREVENTIVE

Dowborn Chemical Company
Dept. CO, 310 S. Michigan Ave., Chicago 4, Ill.
New York • Los Angeles • Toronto

30,000 Data Sheets On File TO HELP YOU FIGHT CORROSION

A typical corrosion data sheet—
one of more than 30,000 on file
at INCO that may be applied
to your corrosion problems.

WHEN you bring a corrosion problem to The International Nickel Company for advice . . . what attention does it receive?

First, reference is made to a completely-indexed file of corrosion data. This quickly determines the existence of any information applicable to your particular problem.

Data produced by INCO's corrosion engineering research during the past 38 years, plus information abstracted from the technical literature, are catalogued on over 30,000 Corrosion Test Data sheets. These are filed for ready reference by corrosive medium . . . by industry . . . by metal.

Since the data are not confined to Nickel alloys, an ample basis is provided for direct comparison with other materials that may have been used previously or are being considered.

The files are kept up-to-date. For corrosion research by INCO and others never ends. As new processes are developed and as new materials become available, additional data are supplied by continuing corrosion research.

Thus, designers and buyers of equipment will find that many times the solution of a problem is indicated by no more than the application of the existing data. But, of course, even this mass of information by itself is not enough to solve every corrosion problem brought to INCO.

When something more is needed, steps can then be taken to fill the gap.

For example, new tests

CORROSION TEST DATA								
				FILE NO. 44 C 1118				
				SPEC. NO. 8				
				DATE 6/20/64				
CORROSIVE MEDIA & CONC:					COMPANY: XYZ Soap Company			
Liquid NaCl 24.00%, glycerine 54.00%, Na_2SO_4 1.76%, free HgO .015%								
crystallized solids - NaCl 11.99%, Na_2SO_4 1.14%								
INDUSTRY: Soap								
PROCESS INVOLVED: Recovery of crystallized salt from partially concentrated soap lye.					DURATION OF TEST: 50 days			
PRODUCTS TESTED: Zinc Coated Steel					AERATION: Agitated with air			
TESTING APPARATUS: Circular dish containing 15 liters of test solution.					AGITATION: 100-200°F. (Avg. 150°F.)			
LOCATION OF SECTION: Several feet from top of tank directly under point of discharge line from pump.					TYPE OF TEST: Open			
TIME OF TEST: Open					GEN. REMARKS: Specimen continuously agitated with compressed air. Level in feed tank varies so that approximately 1/3 of time spec. is completely immersed in slurry. Rest of time is subject to discharge coming overboard from pump.			
CORROSION RATE mm./hr. mm./hr.								
Metal	Spec. Code	Rate	Rate	Rate	Surface	Max. Immersion		
		mm./hr.	mm./hr.	mm./hr.	mm.	mm.		
Monel	MnB	0.3	0.3	0.00006	.000	.000		
	MnB	0.3	0.3		.000			
K-Monel	KMn	0	0	0	.000	.000		
	KMn	0	0		.000			
B-Monel	BmN	0.7	0.8	0.00013	.000	.000		
	BmN	0.7	0.8		.000			
Nickel	Ni	0.6	0.7	0.00018	.000	.000		
	Ni	0.6	0.7		.000			
Inconel	INo	0.09	1.1	0.00018	.000	.000		
	INo	0.09	1.1		.000			
Mild Steel	PbF	84	86.1	0.016	.005	.004		
	PbF	84	86.1		.006	.008		
Hi-Nickel	JN	0	0.3	0.00007	.000	.000		
	JN	0	0.3		.000			
	JN	0.15						

can be made in your own plant. Special tests can be carried out in INCO's Research Laboratories. Field tests can be initiated at one or more of INCO's atmospheric or marine

testing stations.

These facilities are available to you. All you need do, is bring your corrosion problem to the attention of INCO corrosion engineers.



THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N.Y.

**FOR
CATHODIC
PROTECTION OF
PIPE LINES**

**THE NEW JERSEY ZINC COMPANY'S
HIGH QUALITY
MIX NO. 1
ROLLED ZINC PLATES**



THE NEW JERSEY ZINC COMPANY

PRODUCTS DISTRIBUTED BY

THE NEW JERSEY ZINC SALES CO.

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New York 7, N.Y.**

**221 No. LaSalle Street
Chicago 1, Ill.**

Guardian of the NAVY'S LIFE LINE!

Through the steaming jungles of Panama—from Cristobal to Balboa—extends one of the most strategically important pipe lines in the world. Carrying vital oil supplies from ocean to ocean, the Navy's 46-mile "jugular vein" includes hundreds of miles of metal pipes and dozens of huge storage tanks.

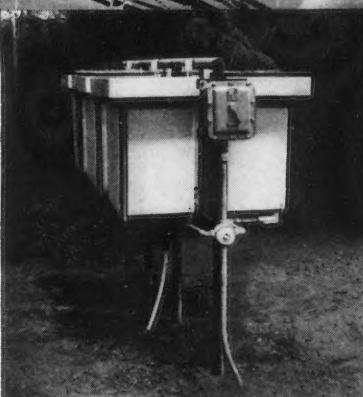
FEDERAL's CATHODIC PROTECTION

Safeguards \$20,000,000 Pipe Line
Against Electrolytic Corrosion

The Panama pipe line's unusual soil conditions, including subterranean electrical currents caused by magnetic storms, made protection against galvanic corrosion a tough job—a job for Federal Cathodic Protection equipment.

This installation includes eighteen 50-amp, 12-volt Federal rectifier units, mounted singly or in groups and suitably spaced for effective protection along the line. To prevent corrosion from pipe-to-soil galvanic currents, the combined protective equipment delivers a total of 800 amperes d-c, flowing from soil to pipe.

Hundreds of similar installations for pipe lines, storage tanks, and cable systems, are safeguarding valuable investments and maintaining uninterrupted service. Federal engineering can point the way to the most economical protection for your equipment too.



Group installation of six 50-amp, 12-volt Cathodic Protection units safeguarding vital Panama pipe line. Operating silently, without moving parts, these units give dependable service under the most severe atmospheric and temperature conditions. This unique corrosion control project was investigated and protective application engineered by Ebasco Services Inc., N. Y. subcontractors to Williams Brothers Corp., N. Y. builders of the pipeline.

Write for free booklet explaining the theory and application of Federal Cathodic Protection. It's a valuable addition to your reference files.

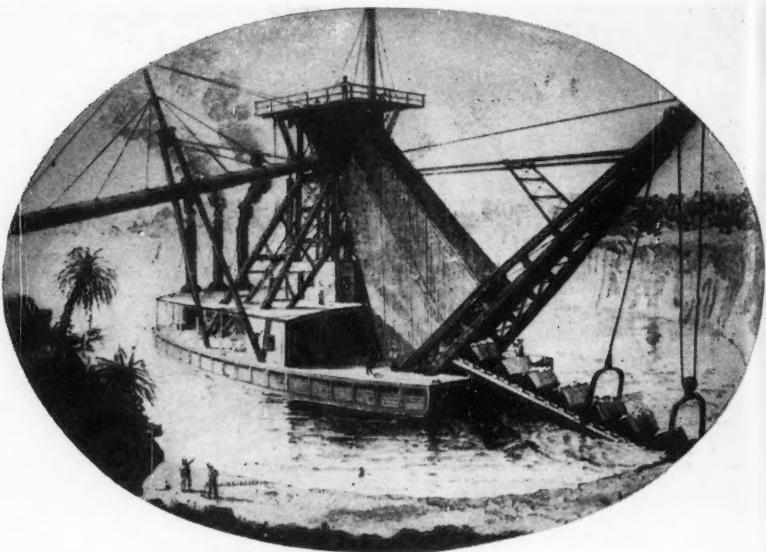


Federal Telephone and Radio Corporation

In Canada:—Federal Electric Manufacturing Company, Ltd., Montreal
Export Distributor:—International Standard Electric Corporation



Newark, N.
New Jersey



Famous Facts

The Panama Canal, constructed with such huge dredges as this, was officially opened to commerce in August, 1915. Interest in this project had been active since 1850, and its completion was a major engineering triumph.

Bitumastic Enamel — introduced in the early 1850's — had a long record of excellent performance as a protective coating, and was applied to the lock gates and penstocks of the Panama Canal in 1912-14. Inspected in 1925, enamel

and steel showed no deterioration from the corrosive waters of Gatun Lake.

Bitumastic Enamel's high viscosity provides a thick protective coating with good adhesion and great flexibility under stress, properties assuring maximum protection to oil, gas and gasoline lines. Impervious to water and chemicals present in highly corrosive soil, Bitumastic gives long-lasting corrosion protection under all conditions of soil and climate.

WAILES DOVE-HERMISTON
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Corrosion

An Official Publication of the
**NATIONAL ASSOCIATION OF
CORROSION ENGINEERS**



Volume II

SEPTEMBER, 1946

Number 3

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CORROSION ENGINEERS**

ELTON STERRETT, Executive Secretary

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Telephone Cable Sheath Corrosion in Non-Stray Current Areas

By J. M. Standing

American Telephone and Telegraph Company, New York, N. Y.

CURRENTS straying from grounded direct current traction systems have contributed in large measure to the corrosion problem on underground telephone cables. In more recent years, the telephone underground plant has been extended into outlying areas, where the effects of stray traction currents are not apparent. At the same time, many of the direct current traction systems have been replaced with other forms of transportation. These circumstances are combining to place an increasingly larger proportion of the telephone underground plant in areas where there are no stray traction currents. Experience indicates that forms of corrosion, which were formerly either overshadowed in importance by stray current corrosion,

or which were automatically mitigated by the measures applied to combat stray current corrosion, are becoming important problems. It is estimated that in the Bell System more than 50 percent of all underground sheath failures due to corrosion are the result of non-stray current phenomena.

Though costly repairs may be required, few sheath failures caused by corrosion result in important reactions on telephone service. It may be interesting to describe some of the methods employed by the telephone companies to insure service continuity. When a hole occurs in the cable sheath, the conductors within the cable, which are paper insulated, may be exposed to moisture. Wet conductors result in noise,

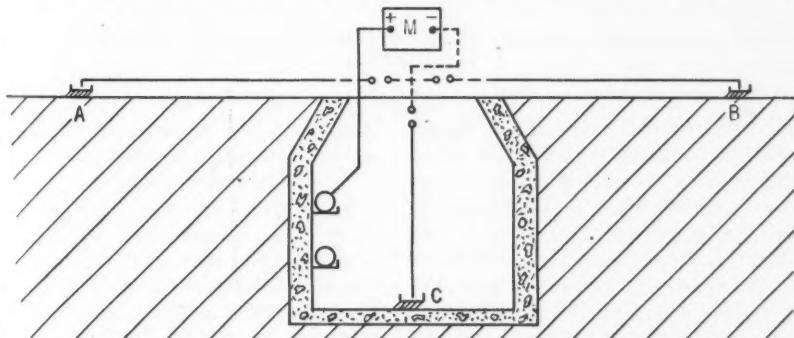


Figure 1—Method for locating the anodes and cathodes of local corrosion cells separated by considerable distances, corrosion currents generally being known as "long line" currents. This method involves measurement of earth gradients around the cable and may be applied to telephone cables at manholes.

cross talk and possibly service interruption. To prevent the entrance of moisture, the more important intercity cables and all of the cross-country cables are filled with dry nitrogen gas maintained at a pressure of about nine pounds per square inch. This serves not only to keep moisture out of the cables, but also to provide a means of indicating the presence of a hole in the sheath. The latter feature is accomplished by installing at intervals along the cable pressure-operated contacts, designed to close when the pressure falls below normal, as it does when a leak occurs. These contacts in turn are

If necessary, additional gas can be supplied near to the leak, thus safeguarding the cable until permanent repairs can be made. In local cables, because of the many branches that exist, the application of gas pressure is more difficult. Here reliance is placed on the fact that it takes some time for moisture to penetrate past the outer layer of conductors. If a hole occurs in the sheath and moisture enters the cable, a warning usually is given by reports of minor service reactions on a few circuits in the outer layer of conductors. Prompt location of the conductor troubles by electrical means enable

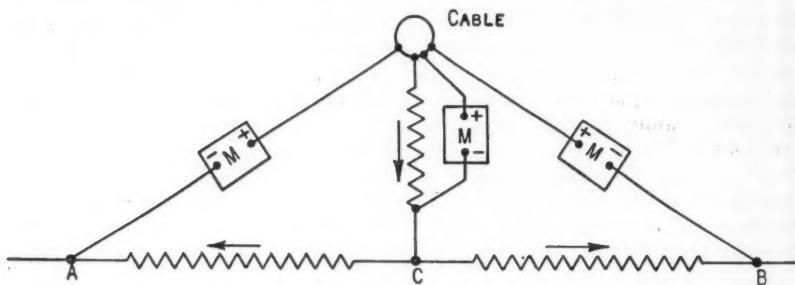


Figure 2—Electrical counterpart of Figure 1, indicating leakage paths between the cable and earth.

arranged to short circuit an "alarm pair" in the cable. At a control office this pair is connected to an alarm circuit which, when it operates, notifies the attendant that trouble has occurred. By measuring the resistance of the short circuited alarm pair, the attendant can find out which pressure contacts have operated and can determine the approximate location of the trouble. The field forces then can be promptly dispatched to the approximate trouble location where a more precise location can be made.

repairs to be made before major service interruption results.

Corrosion Testing

As discussed above, steps are taken to minimize the effects of holes in the sheath after they occur. Another important line of defense lies in preventing the occurrence of holes in the sheath. In the case of holes caused by corrosion, this first involves the location of places where corrosion is likely to occur. In the stray current area, this has been done by determining the potential

between holes
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is an

Water
glue
edge

Enlarg
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Figur

between sheath and earth at manholes. In making this measurement a piece of lead cable sheathing is used for the ground electrode, and it is assumed that there is no galvanic potential difference between this electrode and the cable sheath. With this assumption, any observed potential difference is caused by current between the sheath and earth. If the sheath is positive to earth it is an indication that current is leav-

ing the sheath and consequently exposing it to electrolysis. This procedure, supplemented by measurements of current on the sheath, has proved very satisfactory in stray current areas. Experience indicates, however, that it is not entirely reliable when applied in the non-stray areas. One reason for this is that the galvanic potential between the lead electrode and the sheath, which was successfully neglected in the stray

area, becomes an important part of the total cable-to-earth potential in the non-stray area. In general, if the cable-to-earth potential measured to a lead plate is less than about ± 0.1 volt, the direction of current is doubtful. Also, it is possible for corrosion to be caused by local action, which is limited to a very short section of the sheath between manholes. In this case the corrosion currents probably are confined to the duct in which the cable is lying, and do not affect to any large extent the potential between the sheath and earth at manholes.

In some cases the anodes and

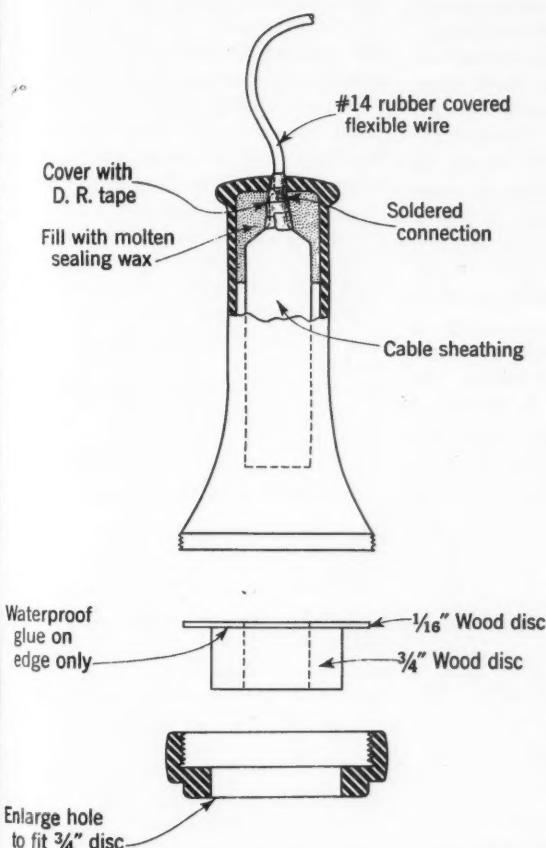


Figure 3—Lead Chloride half cell, using 144 receiver shell.

cathodes of local corrosion cells may be separated by considerable distances. In these cases the corrosion currents are generally known as "long line" currents. Where this type of action is taking place, the cable-to-earth potential at manholes may be affected by the corrosion currents.

A method for locating the anodes and cathodes of this latter kind of a corrosion cell that has been tried, and which so far seems to have some promise, involves the measurement of the earth gradients around the cable. Half cells are used instead of lead electrodes for the earth contacts. This method is by no means new and is no doubt familiar to many corrosion engineers. It may be applied to telephone cables at manholes as indicated in Figure 1. Three potential measurements are required: Cable to earth close to the cables, as within the manhole at C, and cable to more remote earth at points A and B on either side of the conduit line. Figure 2 shows the electrical counterpart of Figure 1 and indicates the leakage paths between the cable and earth. From a consideration of the three potential

measurements, it can be determined if there is a current in the earth toward the cable or away from it. Suppose, for instance, that the following measurements are obtained:

Cable to A = +0.15 volt
 Cable to B = +0.20 volt
 Cable to C = +0.10 volt

This would indicate that point C on the earth is at a higher potential than either of points A and B, and consequently that there is a current in the earth away from the cable. The purpose of making a test to each side of the cable is to guard against the possibility of being misled by transverse currents in the earth.

As of possible interest, Figure 3 illustrates a form of half cell which has been used in making these measurements. As is evident, a telephone receiver shell is used as the housing. An electrode of lead sheathing, surrounded by a solution saturated with lead chloride and potassium chloride, is employed. In a town where one of these cells was being used to make contact to the surface of a street, considerable interest was aroused among the public who felt sure that the cell was being used to tap in on telephone conversations.

Experience with the use of the

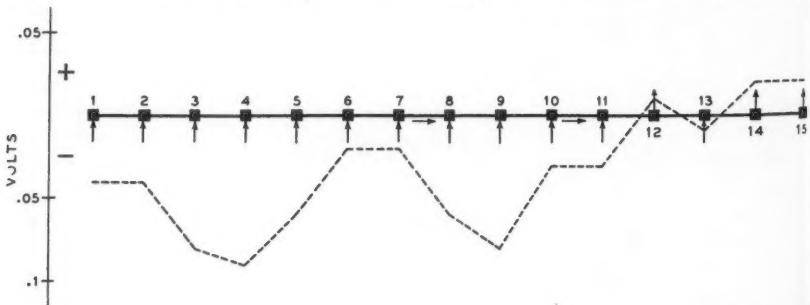


Figure 4—Difference in potential between earth outside manhole and earth inside manhole.

test method outlined is somewhat limited. Data obtained in one of the cases where it was used will serve to illustrate the type of information it provides. Figure 4 shows the cable layout in a small town. Plotted opposite the manhole locations are the differences between cable-to-earth potential outside the manholes and cable-to-earth potential inside the manholes. This difference gives the potential of the earth inside the manhole with respect to earth outside the manhole. If this difference is positive, it indicates a IR drop in the earth away from the cable and vice-versa. The earth current directions found in this manner are indicated by the arrows perpendicular to the sheath. Sheath current measurements were also made and the direction is indicated by the arrows parallel to the sheath. These data indicate current in the

earth toward the cable at all manholes except in the vicinity of manholes 12, 14 and 15 when the reverse is true. The direction of sheath current is in agreement with this condition. In this case corrosion failures had occurred in the sections between manholes 13 and 14 and 14 and 15.

Conclusion

It will be evident from the remarks in this paper that a great deal of work needs to be done before corrosion on cables in non-stray areas can be located with assurance. Many different tests have been suggested in the past, and there is little doubt that ideas will continue to be presented. The final test of the reliability of any method, however well founded it may be in theory, lies in its performance record. The best way to determine this is by experience.



Laboratory Studies for Determination of Organic Acids As Related to Internal Corrosion of High Pressure Condensate Wells

By E. C. Greco and H. T. Griffin

United Gas Pipe Line Company, Shreveport, Louisiana

TODAY the Oil and Gas Industry is experiencing severe internal corrosion of high-pressure gas-condensate well tubing and well-head fittings. This presents the industry with a serious economic as well as with a safety problem. The expense of shutting in a well and replacing the corroded tubing, along with the loss in production during the time the well is shut in, increases the cost of production and decreases the revenue realized from the field as a whole.

The economic importance of internal corrosion of tubing in high-pressure gas-condensate wells was very well brought out in a paper presented before the Annual Convention of the N.A.C.E. in April, 1944, by T. W. Johnson (1). He states that, "due to the uncertainty of where internal corrosion has occurred, precautions have to be taken which increase the cost of killing the well and replacing the corroded equipment."

In a paper before this same convention, W. F. Rogers makes the statement (2), "Corrosion of oil well subsurface equipment is as old as the industry, and is a subject which has always received some attention. Seldom, however, have these corrosion problems approached the economic importance of corrosion of high-pressure well equipment."

McGuire (3) states that, "severe internal corrosion of tubing is occurring in the Cotton Valley, Louisiana, field," and that, "a number of strings of tubing parted in a six months' period."

It was in the summer of 1942 that severe corrosion of well-head fittings was first noticed (4). This unusual type of corrosion was noted first in wells in the Opelika field, Texas. Rates of corrosion sufficiently rapid to require the replacements of Christmas tree fittings within several weeks were found. A paper was presented before the Convention of the National Gasoline Association of America in April, 1943, describing the corrosion of wells in Opelika field. Before this time, very little attention had been given by the Oil and Gas Industry to corrosion of high-pressure condensate wells. There is little doubt, however, that replacements of tubing and well-head fittings had been made prior to this time, but for some reason the severity of the problem went unnoticed.

Now that a number of companies have made a thorough investigation of their wells, the problem has taken on tremendous proportions. Severe corrosion has been found where it was thought only mild corrosion existed. At present, the problem of corrosion of high-pressure condensate

wells has taken a prominent place in the research laboratories of these companies, as well as in the laboratories of several well known institutions of research and learning. It is not too difficult to imagine the great cost in man-hours and materials that corrosion of high-pressure condensate wells consumes for the Oil and Gas Industry each year. Nor is it difficult to realize the loss in production brought about. At present, the problem has become very broad as well as complicated; nevertheless, it is being studied from several different points.

It had been the opinion of several investigators that all corrosion occurring in high-pressure condensate wells could be attributed to carbon dioxide found in the gas. But wells in the same field were found affected by different degrees of corrosion, yet with the same amount of carbon dioxide in the products produced from the wells. This would seem to indicate that some yet unknown corrosive agent is responsible for the degree of corrosion found in condensate wells. This is probably what led Dr. Paul Menaul to find the organic acids present in the condensate water. He published data in the November, 1944, *Oil and Gas Journal* on the extraction of organic acids of the fatty acid series from condens-

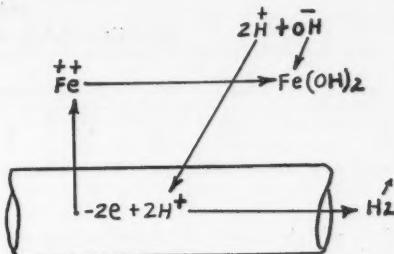


Figure 1—Normal corrosion of iron in water.

ate water. His findings served to shed a different light on the existing problem of corrosion. At present, it is a very well established fact that organic acids are a large contributing factor in the corrosion occurring in condensate wells.

This particular type of corrosion seems to be spread over a wide area along the Gulf Coast, extending several hundred miles inland. It occurs in most all high-pressure condensate wells producing from deep formations. We have noticed excessive corrosion in several of our wells in this locality. In one gas-condensate well along the Gulf Coast, an unusually high rate of corrosion is being experienced. This particular well is producing from 13,200 feet. The tubing in the well was replaced after four years of service and was found to be badly corroded.

In November, 1944, laboratory work was begun on the problem by United Gas Pipe Line Company. It was decided that the research should be carried on with the following objectives in mind:

1. To isolate from condensate waters organic acids and other mate-

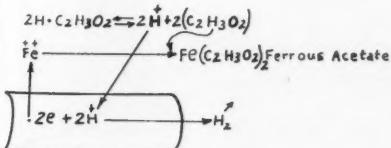


Figure 2—The increase of corrosion of steel by organic acids.

TABLE I
Analysis in P.P.M. of Condensate Water

SAMPLE	Ferric Oxide	Silica	Carbonate	Sulphate	Calcium	Magnesium	Sodium	Chloride	T.S.
A.....	328	2	243	1	42	1	180	63	860
B.....	355	2	105	6	8	1	221	231	929
C.....	178	2	58	7	6	0	239	307	797

rials which might be contributing to the corrosion of condensate wells.

2. To determine the organic acid content of a number of waters in several fields.

3. To see if a correlation could be found between the concentration of organic acids in the water and the degree of corrosion taking place in the wells.

4. To work out a method by which these acids could be separated from each other. (This is still in process.)

The waters for study were chosen from several different fields. This included fields where this phenomenal type of corrosion was suspected to exist, and fields where no corrosion of wells had been noted or reported. Water was taken from wells of fields on the Gulf Coast, while some wells sampled were located several hundred miles from the Gulf Coast proper. Waters ranging from condensate waters to salt waters were studied.

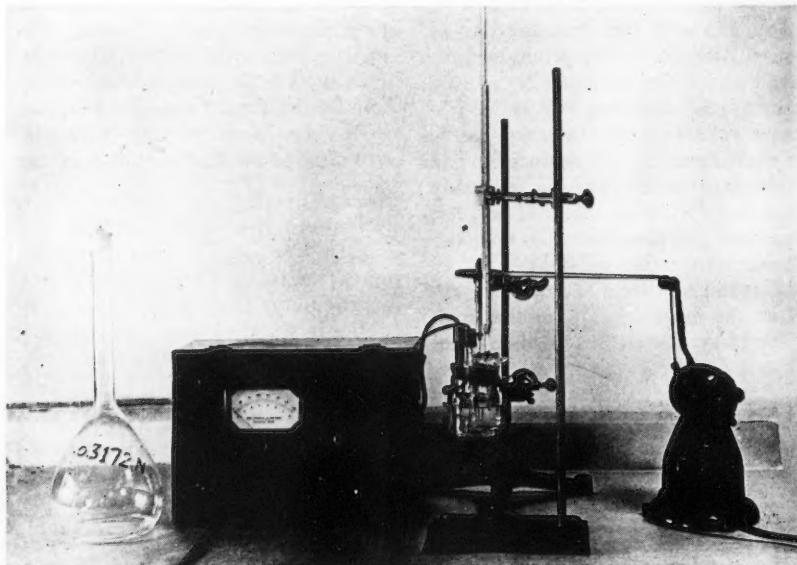
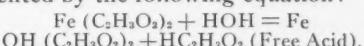


Figure 3—Apparatus used in conducting experiments.

Mineral analyses of some of the condensate waters studied appear in Table I (6).

Samples A and B are from waters produced from 13,200 ft., along with the gas and hydrocarbon condensate. Sample C is from 10,300 ft. When heated, these waters emit a pronounced mingled odor of butyric, valeric, and acetic acids. In determining the pH of these waters before and after heating, it will be found that the pH after heating is lower, indicating the liberation of free acid materials. Largely, the iron in these waters exists as ferrous iron. For example, Sample A was found to have a pH of 5.75; after heating it

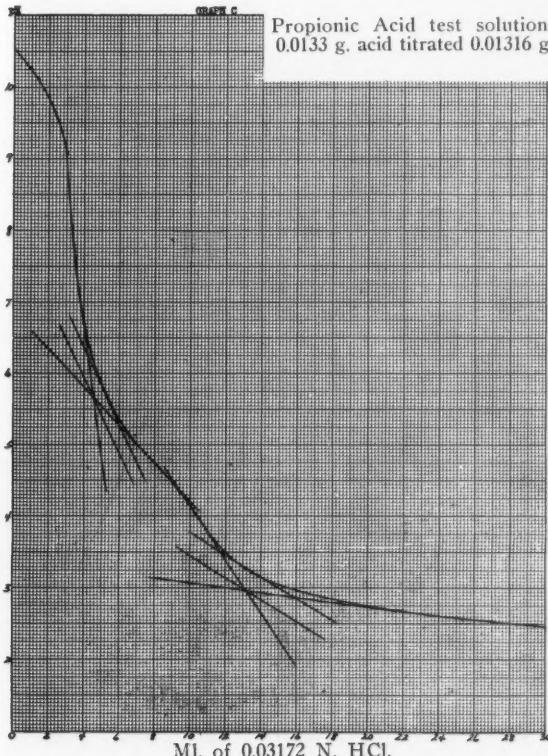
to 200° F. for a few minutes, the pH dropped to 4.61. This drop in pH is due to the hydrolysis of the iron salt of the acid which may be represented by the following equation:



These condensate waters contain organic acids free and combined as $\text{Fe}(\text{C}_2\text{H}_3\text{O}_2)_2$.

The organic acid content of the three waters in Table I was determined by three different methods. In sample A, the organic acid content was determined by the extraction method published by Menaul (5). Fourteen liters of the water were heated to drive off carbon dioxide, and sodium hydroxide added to fix the pH at 12. (Menaul fixed the pH of his sample at 9.) The dried salts were extracted, first with dry ether, and then with dry ethyl alcohol. The alcohol - extracted salts were dried, treated with 20 percent sulfuric acid and extracted with dry ether. The ether was distilled, leaving 9.7770 grams (698 P.P.M.) of a mixture of organic acids.

Along in the process in the ether extraction of dry salts, the odor of phenol was detected when the ether was distilled off. By extracting,



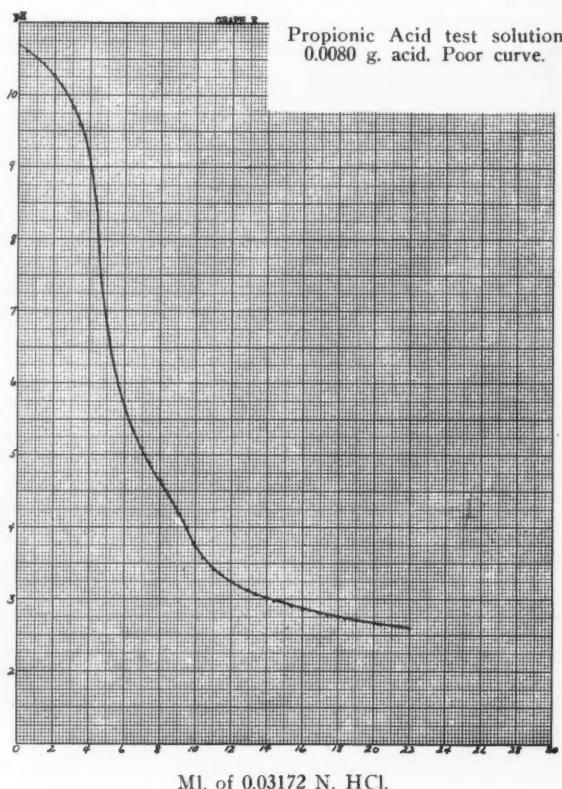
brominating and recrystallizing from alcohol, it was possible to identify this material as phenols. 5.4 P.P.M. of this phenolic material was extracted from the water. The mixture of fatty acids extracted was found to have reducing characteristics on silver ammonium hydroxide solution, indicating the presence of a reducing acid. Formic acid possesses strong reducing properties.

In the analysis of Sample B for organic acid content, a method of extraction-distillation was used. The water was found to have a pH of 5.35 as it came from the separator. After heating it for a few minutes at 200° F., the pH dropped to 4.60. Twenty-two liters of the sample were taken for evaporation, and the pH fixed at 11 with 10 percent sodium hydroxide solution. This was heated for several minutes and the precipitated iron removed by filtration. The sample was next evaporated over a gas flame until the total volume was reduced to about one liter; then the evaporation was completed on the steam bath.

The salts resulting from the evaporation were neutralized with dilute

hydrochloric acid until their solution became slightly acid. Then sodium carbonate was added until the solution was only slightly alkaline. Carbon dioxide was bubbled through it for 45 minutes, and the whole steam-distilled to separate the phenols.

The collected steam distillate was made alkaline with sodium hydroxide and extracted with ether. The distillate was next made acid with 85 per cent phosphoric acid and again extracted with dry ether. This gave 4.13 P.P.M. of phenolic material in fairly pure state. The material possessed the characteristic odor



of phenol and when brominated and nitrated it formed the 2:4:6 Tri-bromo and Tri-nitro compounds.

The main sample was evaporated down and dried free of moisture. The resulting dry salts were placed in a Soxhlet extracting thimble, and extracted several hours with dry ethyl ether to remove the ether soluble materials. The ether was dried completely from the remaining salts, first on the steam bath and then in the air oven at 204° F. The salts were next extracted with dry alcohol to recover the sodium salts of the acids. The alcohol was distilled off and the salts dried.

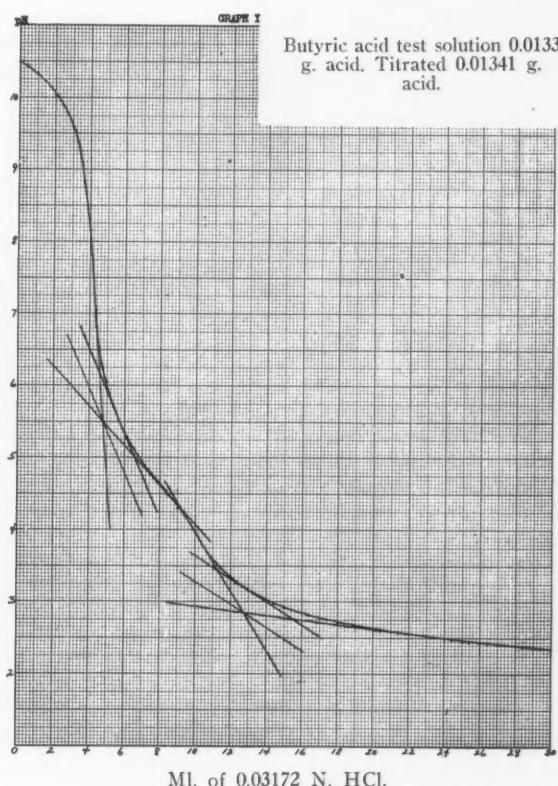
By means of a suitable vacuum distillation apparatus 85 percent phosphoric acid was heated to 200° C. under a vacuum of 20 m.m. of mercury to remove water.

The recovered sodium salts of the acids were placed in the vacuum distillation apparatus, and an excess of the pretreated phosphoric acid added. The organic acids were distilled over at 20 m.m. of vacuum. By this method, a water white mixture of the acids along with a small amount of water was recovered. The water and acids were separated by

extraction with dry ether, and the ether removed by distillation. The recovered acid mixture was weighed and found to be 779 P.P.M.

Sample C (Table I) was found to have a pH of 6.30; after heating the pH dropped to 4.65. The acids in this sample were extracted by using the above method. The total organic acids distilled over under vacuum from pretreated phosphoric acid was found to be 341 ppm. (0.3410 grams/liter). Of this mixture 246 P.P.M. (0.2460 grams/liter) were found to distill over between 100°-185° C.

The neutralization equivalent of



the above fraction gave a value of 102.16. Since the molecular weight of N-valeric acid is 102.13, then this mixture of acids has an average molecular weight equal to that of N-valeric acid. This mixture of acids had no reducing action on silver ammonium hydroxide solution. This would indicate the absence of formic acid.

A heavy salt water from another field was also examined for organic acid content. The field from which this water was taken has shown a comparatively small amount of corrosion and cannot, therefore, be classed as a corrosive field.

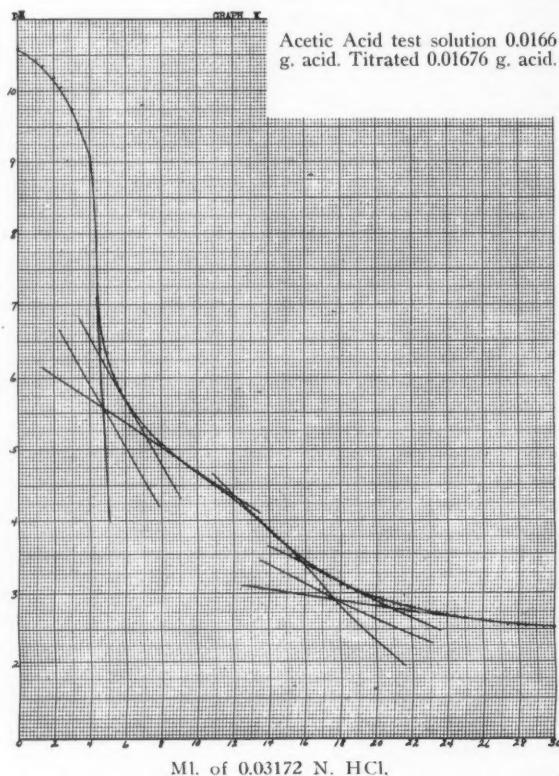
The sample of water was found to contain 739 P.P.M. of iron calculated as ferric oxide. However, most of this iron can be attributed to the corrosive action of the dissolved chlorides; the organic acids being responsible for only a small part of the total iron.

The pH of the water was found to be 6.88; after heating it below the boiling point for a few minutes it dropped to 5.88. The 13 liters of this water taken for analysis contained 1092 grams of dissolved salts, making it quite difficult to extract the acids without loss. Nevertheless, the recovery was 0.0352 grams/liter (35.2

P.P.M.). Since this analysis, the organic acid content of a number of waters from the safe field has been determined by the electro-metric-titration method and found to range from 20 to 102 P.P.M. (See Table V).

The acids recovered were of the formic acid homologues series, having a strong characteristic odor of propionic acid. The neutralization equivalent was determined and found to be 74. The molecular weight of propionic acid is 74.08.

Judging from this sample, it might be concluded that salt waters also contain organic acids of the fatty



acid series, possibly tied up as Fe (C₃H₅O₂)_n.

A sample of water from the high-pressure gathering system of a compressor station of a third field was examined for organic acids by the extraction-distillation method, and by the electrometric titration method. This sample was made up of a mixture of waters produced from a number of wells in the same field. The following are the results of the analysis:

pH of sample as received....	6.60
pH of sample after heating to 212° F.....	6.18
Total sales	1,374 ppm.
Total iron as ferric oxide.....	116 ppm.
Total chlorides as sodium chloride	1,165 ppm.
Total carbonates as sodium carbonate	141 ppm.
Total organic acids	
(By extraction-distillation method)	26 ppm.
(By electrometric titration method)	25 ppm.

The mixture of acids extracted reduced ammoniacal silver solution. Since formic acid has reducing qualities it may be concluded that this acid is present.

The gas-condensate field from which the above sample was taken has produced approximately 12 years, and has shown no signs of serious internal corrosion of tubing or well-head fittings.

In order to check the extraction-distillation method for the determination of organic acids in condensate waters, and also to provide a faster method for their determination, an electrometric titration method was worked out along the lines of that used by S. E. Buckley of the Humble Oil and Refining Company (?).

TABLE II
Propionic Acid Test Solutions

GRAPH	(1) Actual Grams Acid	(2) Grams Acid from Titration	(3) Deviation in Grams
.....	0.0196	0.01950	0.00010
.....	0.0166	0.01692	0.00032
C.....	0.0133	0.01316	0.00014
.....	0.0110	0.01150	0.00050
E.....	0.0080	Poor Curve	.....
.....	0.0050	Poor Curve	.....

Note: Not all the graphs are included in this paper. Graphs C and E are included as examples.

The method of the writers, which is a modification of Buckley's method, employs a Beckman industrial model pH meter having a calomel and glass electrode. The titration vessel consists of a jar covered with a cork stopper containing the electrodes, a 50 ml. burette, and a mechanical stirrer.

The method was tested against standard organic acid solutions with the following objectives in mind:

1. To determine the grams of acetic, propionic, N-butyric, and N-valeric acid necessary to give a curve with good deflection points.
2. To determine if the above four acids give the same type of curve.
3. To establish the accuracy of the method on dilute solutions of these acids singly and in mixtures.

Four basic solutions were made up containing 0.00040145 grams acetic acid per ml., 0.00041220 grams propionic acid per ml., 0.00041607 grams N-butyric acid per ml., and 0.00042001 grams N-valeric acid per ml. The propionic, N-butyric and N-valeric acids were purchased from the Eastman Kodak Co. These solutions were all standardized against a 0.05N sodium hydroxide solution which had been standardized against Bureau of Standards benzoic acid.

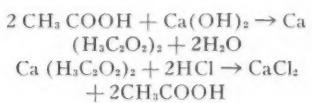
To make up a test solution the

TABLE III
**Comparison of Results of the Electrometric Titration of Test Solutions
of Three Different Acids**

GRAPH	Test Solution Grams Acid	Grams Acid by Electrometric Titration			Deviation In Grams
		Acetic	N-Butyric	N-Valeric	
K.....	0.0166	0.01676	.....	.....	0.00016
.....	0.0196	.....	0.01984	.....	0.00024
I.....	0.0133	.....	0.01341	.....	0.00011
M.....	0.0196	.....	.....	0.01976	0.00016
.....	0.0110	.....	.....	Poor Curve	.....

Note: Graphs K, I, and M included in this paper as examples.

exact volume of the acid solution was measured from an accurately calibrated burette. Each test solution was titrated with 0.03172N hydrochloric acid and the pH readings taken at each 0.4 and 0.6 ml. addition of the standard acid. The volume of the test solution to be titrated was kept fairly constant at 120 plus, a maximum of 30 mls. The alkalinity of the test solutions was fixed as close to a pH of 10.5 as possible by treating them with solid calcium hydroxide. Each sample was filtered before being titrated to remove the excess calcium hydroxide plus any calcium carbonate formed by the carbon dioxide present in the water.



Thirteen test solutions containing from 0.0196 to 0.0050 grams of organic acids were made up. Two of these were composed of mixtures of the four acids. (See Table IV).

Table II is a comparison of the results obtained on six test solutions of propionic acid. Column (1) gives the grams of acid in each test solution. In column (2) are the results after plotting the graphs of the elec-

trometric titrations. Column (3) shows the difference in grams between the actual weight of the acid in the test solutions and the results of the electrometric titration.

Table III tabulates the results of five different determinations on three different acids. Note that 0.0110 grams of N-valeric acid gave a poor curve, in that the first deflection point in the curve is too straight. The results on acetic, N-butyric, and N-valeric are comparable to the results obtained on the test solutions of propionic acid.

Table IV gives a comparison of the results of the electrometric titration for the four different acids. Col-

TABLE IV
Comparison of Results on Four Different Acids
Results of Electrometric Titration

(1) Grams Acid in Test Solution	(2) Propionic	(3) N-Butyric	(4) N-Valeric
0.0196	0.01950	0.01984	0.01976
	Propionic	Acetic	
0.0166	0.01692	0.01676	.....
	Propionic	N-Butyric	
0.0133	0.01316	0.01341	.....
	Propionic	N-Butyric	
0.0110	0.01150	Poor Curve	.....

TABLE V
Mixtures of the Four Acids

ACID	SOLUTION I		SOLUTION II		RESULTS OF ELECTRO-METRIC TITRATION	
	Percent Acid in Solution	Grams Acid in Solution	Percent Acid in Solution	Grams Acid in Solution	Solution No. 1	Solution No. 2
Acetic.....	40	0.00684	10	0.00166	(3)	(4)
Propionic.....	35	0.00851	15	0.00249		
N-Butyric.....	15	0.00249	35	0.00851		
N-Valeric.....	10	0.00166	40	0.00664	Graph O	.....
Totals.....	100	0.0166	100	0.0166	0.01722	0.01606

Columns 3 and 4 are duplicate determinations, in that the test solutions in column 2, 3 and 4 were made up to contain the exact weights of acids shown opposite them in column 1.

Table V gives the results obtained by using 0.0166 grams of a mixture of the four acids. It also gives the percentage and grams of each acid used to make up each test solution.

In Table II, 0.0196, 0.0166, 0.0133, and 0.0110 grams of propionic acid gave curves with good deflection points, with deviations of 0.00010 to 0.00050 grams from the actual value. (See Graph C.) When the acid content of the test solution was fixed at 0.0050 and 0.0080 grams, the curve had a tendency to straighten out at the first point of deflection, making it impossible to determine the beginning of the acid part of the curve. (See Graph E). Thus, in order to get a good curve by the electrometric titration of organic acids, the solution must contain at least 0.0133 grams of acid. This will also hold true for mixtures of these acids.

In Table IV, the results appear close enough to the true value of each test solution to conclude that the electrometric method for the determinations of organic acids is sufficiently accurate for quantitative

work in the evaluation of condensate waters. Converting the values in Table IV to P.P.M., the average deviation from the true values will be in the magnitude of 2.26 P.P.M.

In Table V, the value in column 3 was obtained by using a molecular weight of 73.376. This was determined from the percentages of each of the acids used to make up the test solution. The value in column 4 was arrived at in the same manner by using a calculated molecular weight of 88.804. Using the molecular weight of propionic acid (74.08) in the place of the calculated molecular weight, the value in column 3 becomes 0.01739.

It will be noted from Graphs C, K, I, M, and O that acetic, propionic, N-butyric, N-valeric, and mixtures of these acids give the same type of curve.

Since it has been shown, from previous work by Menaul (5) and the writers, that the neutralization equivalent of the acid mixture extracted from condensate water is 74, calculating the total acidity as propionic acid gives results sufficiently close to the actual to indicate the use of this method in evaluation of condensate waters for organic acid content. The method is simple and

TABLE VI
Comparison of Results by Three
Different Methods

SAMPLE	Electrometric Titration ppm	Extraction Method ppm	Extraction Distillation ppm
A.....	682	698	
B.....	789	...	779
C.....	266	...	246
D.....	25	...	26

rapid, making it possible to determine total organic acid in a number of condensate waters in a comparatively short period of time.

Before determining the total acid content of a condensate water by this method, it is necessary to approximate the aliquot to be taken to give at least 0.0133 grams of organic acids. Should two or more hundred mls. be required, the whole volume is treated with solid calcium hydroxide. It is then evaporated down to a volume of 50 mls. and filtered. The pH should be fixed at about 10 to take care of hydrolysis which takes place during the evaporation process.

Table VI compares results obtained on four different condensate waters by three different methods. On Sample A, the organic acid content of the water was determined by the electrometric titration method and also by the extraction method. The organic acid content of Samples B, C and D was determined by the electrometric titration method and the extraction-distillation method. The results of the electrometric titration method are calculated to total organic acids as propionic acid.

Table VII tabulates the results obtained by the electrometric titration method on 18 different condensate waters from one of our gas-

producing fields. The wells from which the samples were taken are feeding from two different formations. As is apparent, there is a wide variation in the organic acid content of these waters; and none of the samples has organic acid content as high as was found in Samples A, B, and C.

(See Table VI.) Some of the wells in this field have shown moderate corrosion of well-head fittings, but none has been found to be affected by severe internal corrosion. We have, however, been unable to get a correlation between the organic acid content and the degree of corrosion encountered in condensate well-head fittings and tubing.

The mechanism of corrosion of metals and its acceleration by the presence of organic acids may be illustrated as follows: Iron has a normal tendency when in contact with water to lose electrons (become anodic) and pass into solution as Fe^{++} ions. This tendency can be catalyzed greatly by the presence of an electrolyte in the water. Organic acids are electrolytes which ionize

TABLE VII
Electrometric Titration Method

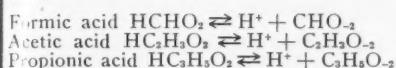
SAMPLE	Total Organic Acid as Propionic ppm
E.....	80
F.....	85
G.....	93
H.....	99
I.....	82
J.....	53
K.....	80
L.....	100
M.....	87
N.....	75
O.....	73
P.....	42
Q.....	51
R.....	59
S.....	20
T.....	67
U.....	102
V.....	47

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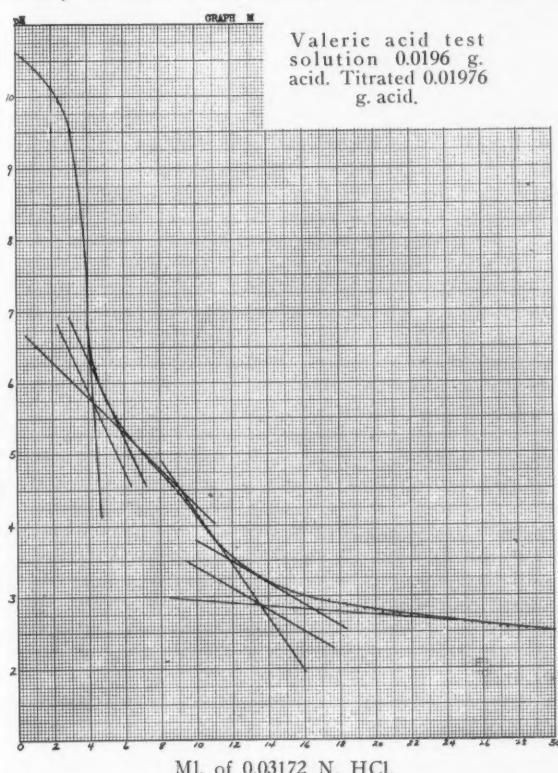
In order for the corrosion of steel to progress it is necessary for the two electrical charges given up by the metal to be removed from its surface. This, in the normal corrosion of iron, is done by the relatively small amount of hydrogen furnished by the ionized waters. (See Figure 1.)

Since we know that the presence of an electrolyte will increase materially the rate of iron removal from

a pipe, the increased rate of corrosion of steel by organic acids may be illustrated by Figure 2.

When organic acids are present, more hydrogen ions are furnished for the removal of the electrons given up by the iron; thus allowing the metal to lose a greater number of its electrons and pass into solution faster. We have now in contact with the metal the hydrogen ions furnished by the ionized organic acids, water, and the carbon dioxide which has formed carbonic acid. As the electrons are now removed much faster from the surface of the iron, the degree of corrosion is amplified due to the presence of those acids.

The other significant factors are temperature, quantity of water produced, rates of flow, and pressure. According to Speller, temperature lowers the overvoltage of hydrogen on the metal, permitting the evolution of hydrogen gas from the metal surface. The temperature in some high-pressure condensate wells ranges from about 260° F. at the bottom of the hole to 165° F. near the top of the tubing string. The amount of water produced will influence the corrosion mechanism in that corrosive agents are dissolved in the water phase; and an increased

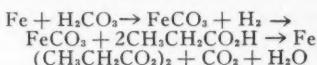


amount of water will insure a continuous supply of carbonic and organic acids to the walls of the tubing. It is also through the water medium that the products of corrosion are removed from the point of action, clearing the metal for further attack.

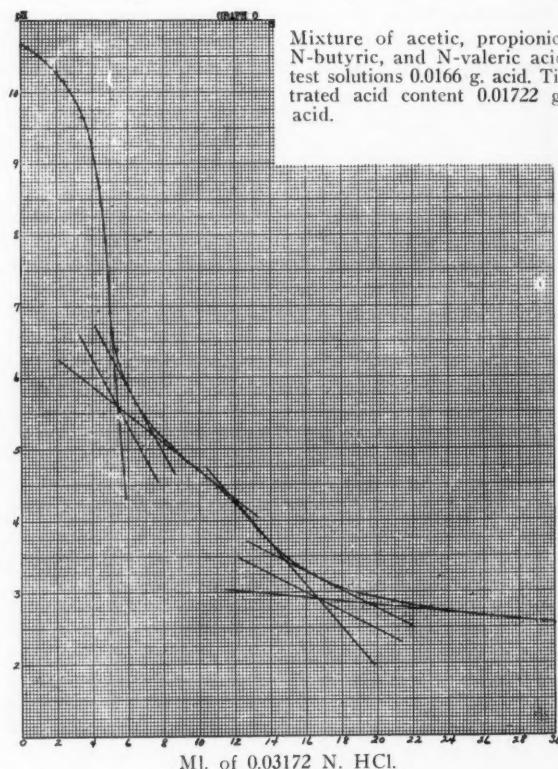
Velocity may bring about increase in corrosion by increasing the frequency of contact between metal and corrosive agent. High velocities set up turbulence in flow, thereby allowing more accelerated removal of corrosion products from the metal surface. High rates of flow also have an erosive action on the corrosion products forming at the surface of the metal.

It is the opinion of the writers that the excessive rates of corrosion found in high-pressure condensate well tubing are due to a combination of two major factors: acid attack plus erosion of the corrosion products by the flowing materials (water, gas, and hydrocarbons). Carbonic acid, formed in the condensate water by the solution of the carbon dioxide from the gas phase and organic acids, attacks the tubing wall. (Gas from these wells has a carbon dioxide content of 0.3 to 2 percent.) The organic acids in the water phase

will also act on the ferrous carbonate, forming the iron salt of the acids and liberating carbon dioxide.



The ferrous salts of the acids, which are very soluble in water, go into solution in the water phase, and are carried away from the tubing wall, leaving fresh bare metal exposed for further attack. The organic acids in the water phase also attack the tubing directly, since they



ionize to a small degree and as such are quite active toward metals. In wells flowing at high velocities, any

corrosion products which are formed and have a tendency to adhere to the metal, thereby offering a protective coating, are removed by the erosive action of the flowing materials (9).

It is now generally agreed among high-pressure condensate well corrosion research workers that organic acids play a major role in the corrosion of condensate well tubings (5). Dr. Menaul subjected mild steel to a one-tenth per cent solution of propionic acid at 150° F. for 12 hours and got 383 P.P.M. in solution. Specimens of tubing pulled from severely corroded gas condensate wells indicate an acid type corrosion.

The results of the present work indicate that concentrations of organic acids in waters from these wells point to a degree, or a potential de-

gree of corrosion. The writers, however, believe some hydrocarbon condensates and waters may have present in them certain natural inhibitory materials, which may tend to protect the tubing to some extent. Wells producing these hydrocarbon condensates and water, even though the waters contain corrosive amounts of organic acids and carbonic acid, will have a milder corrosive history than wells which contain none of these natural inhibitory materials. However, no work has been done along this line as yet. This same view has been expressed verbally by Drs. Lochte and Hackerman, of the University of Texas.

The authors wish to express their appreciation to the United Gas Pipe Line Company for permission to publish this paper.

EDITOR'S NOTE: References follow discussion of this paper.

Discussion

By Paul L. Menaul

Stanolind Oil & Gas Company, Tulsa, Oklahoma

This paper emphasizes the extensive field of the condensate-well corrosion problems, both as to the extensive area over which they are found and the high cost per well involved. These condensate wells are among the highest in initial cost to drill and complete. They are all of the high-pressure type, and the expense of removing and inspecting subsurface equipment, the danger that if equipment fails great loss of production that may result, give this problem particular economic importance. The cost of pulling the

tubing of a well for inspection for corrosion damage may exceed \$10,000, beside the loss of production for many days.

This paper discloses that subsurface corrosion in condensate wells can be detected by chemical laboratory methods.

The discovery that organic acids of the acetic acid series were present in condensate well production gave this industry its first tangible clue toward laboratory methods that could be applicable in predicting this corrosion in an active state, without

going to the expense of killing the well and removing subsurface equipment for inspection.

The laboratory research work, as outlined, and the data presented in this paper show that the severity of corrosion activity to subsurface equipment can be predicted by a laboratory survey and chemical analyses of condensate-well production. Laboratory methods will be developed, if not already prepared, by which subsurface corrosive conditions in condensate wells can be detected, without involving the expensive method of the removal of equipment for examination. Laboratory tests and data involving the expense of a few dollars and a few

hours' time should substitute for a \$10,000 field operation.

Laboratory data have another great advantage over field observation. By laboratory analyses corrosion or corrosive conditions can be detected at individual wells before extensive damage is done, and remedial measures can be taken to protect the equipment in its original undamaged condition; field inspection reveals only the extent of damage already done.

Credit is extended to this paper for the painstaking and excellent research performed and for the fact that the authors have confirmed the causative agent of corrosion in condensate wells.

References

1. T. W. Johnson, Importance of Internal Corrosion of Tubing, Proceedings National Association of Corrosion Engineers, April, 1944.
2. W. F. Rogers, Some Studies of Waters Produced by High Pressure Wells, Proceedings N.A.C.E., April, 1944.
3. T. W. McGuire, The Need for a Method of Detecting Internal Corrosion, Proceedings N.A.C.E., April, 1944.
4. Brown, Estimation of Corrosion Rates by Chemical Analysis, N.A.C.E., April, 1944.
5. P. L. Menaul, Causative Agents of Corrosion in Distillate Fields, Oil and Gas Journal, November 11, 1944.
6. E. C. Greco and H. T. Griffin, Organic Acids Dissolved in Condensate Well Waters, N.G.A.A. Report April 30, 1945.
7. S. E. Buckley, Summary Humble Laboratory Procedure for Determination of Organic Acids in Gas Well Waters, N.G.A.A. Report April 12, 1945.
8. E. C. Greco and H. T. Griffin, Organic Acids in Condensate Well Waters, N.G.A.A. Report June 21, 1945.
9. Frank N. Speller, Corrosion Causes and Prevention, Page 159, 2nd Paragraph.

Designing Water Pipes for Long Life and High Carrying Capacity

By Gairald H. Garrett

Vice President and General Manager Thompson Pipe & Steel Company,
Denver, Colorado

OBTAINING LONG LIFE from water pipes and permanently maintaining a high carrying capacity in them has been the goal of water works and power plant designing engineers for many years. The ultimate goal is not yet reached, but today the problem is much nearer a solution than it was only a few years ago. Today we probably can economically design and build water pipes which have as long a life and as high permanent carrying capacity as is necessary in our expanding and changing economy.

The remarks about to be made are not for the most part my opinions, but are the opinions and experiences of men who have had experience with and are interested in preserving the life of pipelines, men who have used both protected and unprotected pipelines.

Decay of pipelines, whether they be made of steel, cast iron, concrete or any other materials, causes enormous annual financial loss to water departments throughout the country. In severe soil conditions, in many cases, decay of pipelines made of any of these materials, unless they are protected against corrosion and decay, will occur in about equal severity.

Most of the discussions of pipeline corrosion given before the National Association of Corrosion En-

gineers have related to oil pipelines subjected to external corrosion only. External corrosion of water pipelines is, of course, very similar to that of oil pipelines; but in addition there is also internal corrosion. This internal corrosion is caused either by corrosive water, very soft water, or dissolved oxygen in the water.

In discussing methods of increasing the service life of water pipelines it would be well to divide the subject into two parts: First, for mildly corrosive conditions; Second, for more severe to even very severe corrosive conditions. The remarks in general will cover steel pipe.

For Mildly Corrosive Conditions

To arrive at the answer to the problem of designing long-life water pipes to be installed in soils and carrying water, both of which are mildly corrosive, I would like to refer to an examination of two old penstocks, and to a water supply line, which shed some light on the quality of steel to be used in pipeline construction.

A number of years ago a survey was made of several old penstocks, at operating power plants of the Utah Light & Power Company, in the area between Provo and Salt Lake City, Utah. A report on the survey of two of these penstocks will give some very enlightening in-

formation. The two penstocks referred to are Stairs and Olmstead.

The Stairs penstock is 48 inches in diameter with the wall thickness $\frac{1}{2}$ -inch. The static head is 355 feet. It was installed in 1895.

The Olmstead penstock is 60 inches in diameter on the upper end and 48 inches in diameter on the lower end. The wall thickness on the upper end is $\frac{3}{16}$ -inch and the lower end is $\frac{1}{2}$ -inch. The static head is 340 feet. It was installed in 1903.

The accompanying pictures (Figures 1 and 2) are of the two penstocks.

The surveys of these penstocks were made in 1938. The pipelines were examined carefully both externally and internally. Samples of steel were taken and analyzed. Soil and water samples were also taken and analyzed. Analyses of the steel, the soil, and the water are shown in the accompanying tabulation.

The steel used in the Stairs and that used in the Olmstead penstock were similar except for carbon and sulphur content. Olmstead had a little more carbon than did Stairs and a little over three times as much sulphur. The carbon content of steel does affect its resistance to corrosion, but not as much as does the sulphur content. Most good steel

Analysis of Steel						
	C	Mn	P	S	Si	Cu
Stairs.....	0.21	0.42	0.022	0.020	0.019	0.01
Olmstead.....	0.26	0.36	0.010	0.063	0.014	

Soil Analysis—Percent						
	H ₂ O	Ig-nition Loss	Ins.	Fe ₂ O ₃ + Al ₂ O ₃	CaO	MgO S
Stairs Plant.	6.0	15.90	50.82	15.44	17.04	0.80 0.16
Olmstead Plant.....	3.5	17.08	52.00	8.20	21.02	0.87 0.03

specifications limit the sulphur content to a maximum of 0.05 percent. Steel in the Stairs penstock was well under that limitation while the steel for the Olmstead was about 25 percent over this specification.

The analysis of the soil and the water shows that they are both mildly corrosive. The pH of the tailrace waters was close to neutral.

At the time of the survey the Stairs plant had been in operation 43 years. About two-thirds of the circumference of the pipe was buried. The most severe corrosive condition was found just below the ground line, and a few pits were scattered along the pipe to a maximum depth of $1/16$ -inch. Where this pipeline entered the power plant it was entirely exposed, and there was a continuous

Water Soluble Salts—Parts Per Million

	Total Solids	SiO ₂	Fe ₂ O ₃ + Al ₂ O ₃	Ca	Mg	SO ₄	CO ₃	HCO ₃	Cl	Na+K	pH
Stairs Soil.....	400	121	77	54	4	2	0	70	26	16	5.94
Olmstead Soil.....	285	126	54	49	2	13	0	60	14	20	5.69
Stairs Tailrace Water.....	223	10	10	43	6	128	6	60	24	0	7.07
Olmstead Tailrace Water.....	188	11	11	48	6	121	8	66	22	0	7.02

spray of water coming out from underneath the plant which kept the pipe moist at all times. There was practically no corrosion at this point. The plant superintendent had made an internal examination of the pipe in 1933 after it had been in service 38 years. He reported that there were no pits or tubercles on the inside of the pipeline and very little corrosion.

The Olmstead penstock was examined after it had been in service for 35 years. Its condition, from a corrosion standpoint, was not nearly as good as that of the Stairs penstock, or any of the other penstocks examined, for that matter. The installation was not as good an installation as the others, because the pipe was supported on wooden blocks for part of its length and partly on the ground for the remainder of its length. Where it was on wooden blocks it did not have very good cradling.

The result of the survey of the several penstocks revealed that the steel in all but the Olmstead penstock was about the same chemically as in the Stairs. The corrosion on all of the penstocks except Olmstead was very slight. The corrosion of the high-sulphur steel in the Olmstead penstock was rather severe. It is generally known that sulphur is a detrimental chemical to have in steel, but it is not very often that we have an actual opportunity to check the effect of sulphur on corrosion of steel as we did in these Utah penstocks.

Now let's review what happened to the water supply line. This is a six-mile flow line of 18-inch diameter, $\frac{1}{4}$ -inch wall, uncoated steel pipe. It was installed by the City of Boulder, Colorado, in 1907 and takes water from a small reservoir in the mountains several miles west of Boulder. It was laid in a well-drained, gravelly, non-corrosive soil.

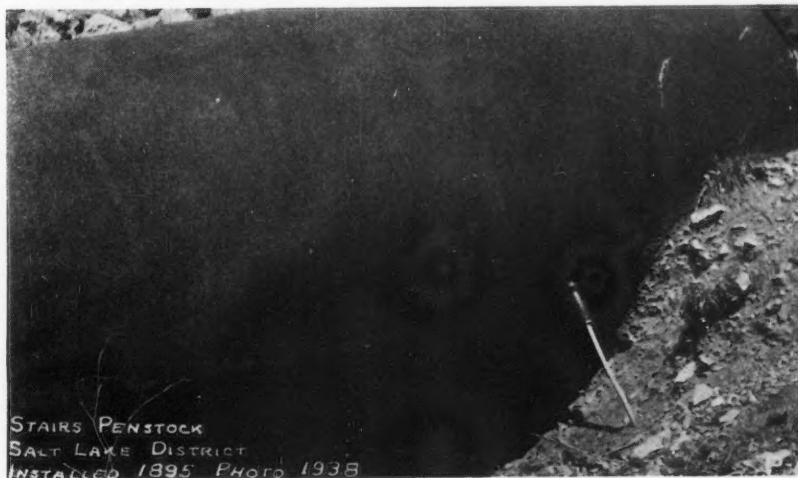


Figure 1—Stairs penstock, 43 years old.

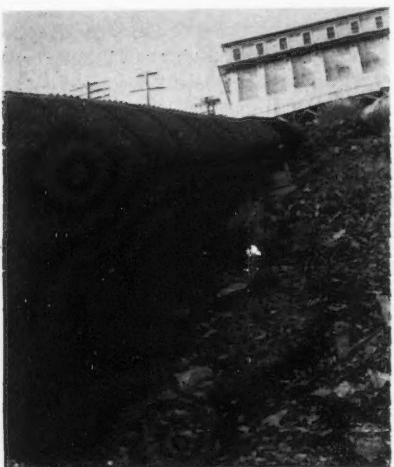


Figure 2—Olmstead penstock, 35 years old.

Water flowing through it is very soft. In 1925 a change was made in the pipeline through an inaccessible part of the mountains. Three lengths of pipe which had been in service for 18 years were removed from the pipeline and laid on the bank, where they remained unmolested until 1938.

In 1938 about half of this pipeline was dug up and replaced with a larger line, which was coal-tar enamel lined inside. A comparison of the inside surface of the three lengths removed after 18 years service with the inside surface of the pipe removed after 31 years service revealed some interesting information. The inside of the three lengths after 18 years of service was perfectly smooth. There were no signs of pitting or tuberculating. The pipe that had been in service 31 years was badly pitted and tuberculated inside. The steel was analyzed and found to be Bessemer grade rimmed quality

steel of the following chemical analysis:

C	Mn	P	S	Si	Cu
0.06	0.32	0.096	0.040	0.004	0.02

It is evident that the change in the condition of the inside of the pipeline some time after 18 years of service was due to the fact that it was made of rimmed steel.

In case you are not familiar with just what is meant by rimmed steel, it will be well to explain some of the types of low-carbon steel. Most steels today are produced in open-hearth furnaces and consist of rimmed, semi-killed or killed quality. Whichever quality is produced depends on how the steel is handled after it is poured into the ladle or into the ingot molds.

Rimmed steel is produced by pouring the steel into the ingot molds and allowing it to cool without adding any fluxing agent. As the molten steel hits the ingot molds, the surface begins to cool down; and as it cools the entrapped gas is forced toward the center of the ingot. This gas, of course, rises to the surface until the center of the ingot begins to get plastic, after which the gas is permanently trapped there. The result is that the surface of the ingot is very homogeneous, while the center of the ingot is spongy.

Semi-killed steel and killed steels are produced by fluxing the gases out of the ingot when the steel is in a molten condition by adding small amounts of aluminum, silicon or other fluxing material. Steel thus produced is homogeneous throughout.

What happened with this Boulder pipeline was that corrosion was taking place slowly and uniformly on the homogeneous surface of the

rimmed steel on the inside of the pipeline. This condition continued for something over 18 years until corrosion penetrated through the thin homogeneous steel and began to attack the spongy part of the steel. Then is when pitting and tuberculating set in. If the steel had been semi-killed quality, then this corrosion would have continued slowly and uniformly for a great many years, and the pipeline would have given long years of service.

It is seldom that we have a chance to study periodic corrosion of pipelines such as was offered by the Boulder installation. Similar results have been noted with rimmed steel in other cases, but the picture was not quite as clear as to just what had happened.

From the results of the study of the pipe installations referred to, it can be concluded that to obtain long life from pipelines operating under mildly corrosive conditions, which lines are not to be protected by fully protective pipe coatings, that care should be given to the selection of the steel; that generally speaking the sulphur content should be 0.05 percent or less, the lower the better; and that a semi-killed quality should be preferred to rimmed quality.

For Severe Corrosive Conditions

For a great many years it was the general practice to use heavy-wall steel pipe for pipeline service. In many cases very little thought was given to a satisfactory protective coating. In many cases, too, not much thought was given to the quality of the steel from which the pipeline was made. In recent years, however, this has been changed, and

a great deal of thought and constructive effort has been devoted to pipeline protective coatings. A review of the behavior of properly coated pipeline installations in various parts of the country will prove the fallacy of the theory of the thick wall design in favor of the protective coating design; the latter theory being one which holds for designing the pipe wall of proper thickness to withstand internal pressure and external loading, protecting the steel from corrosion by hermetically sealing it away from any possible damage from soil, electrolysis or corrosion from activity of the water inside the pipe. As long as the pipe itself is hermetically sealed from the forces of destruction, it will remain in the same condition as it was when it was installed.

A great many types of materials for so protecting water pipes have been brought out in the past. No doubt a great many more will be developed in the future. So far, the material which seems to have done the job most successfully over a period of years is plasticized coal-tar enamel. This may be applied, manually or mechanically, either to the inside or to the outside, or to both surfaces of the pipe. This material is usually applied to an average thickness of $3/32$ -inch, with a plus or minus tolerance of $1/32$ -inch.

Rather than report arguments against the theory of thick wall pipe, or against the use of other types of coating materials, I would like to present a report on the success of coal-tar enamel as a protective coating. To the best of my knowledge there have been no failures of this type of material as a protective coating when properly applied.

Soil Analysis—Percent

	H ₂ O	Ignition Loss	Ins.	Fe ₂ O ₃ Al ₂ O ₃	CaO	MgO	S
G-21.....	20.0	9.02	76.90	5.86	6.04	0.59	0.04
G-22.....	23.0	7.48	82.48	4.04	2.76	0.13	0.52
G-23.....	16.0	5.50	83.80	4.56	3.68	0.33	0.53
G-24.....	17.0	4.56	86.38	4.28	2.62	0.02	0.49
G-25.....	21.0	8.32	80.68	5.88	4.72	0.09	0.38
G-27.....	25.0	12.08	54.76	5.66	15.66	0.14	1.42

The City of Boulder, Colorado, has several pipelines in service which are lined with coal-tar enamel. All of these lines carry water which is active, due to its softness. Previous to using coal-tar enamel-lined pipe, unsatisfactory experience had been had with pipe lined with another type of material. H. C. McClintock, City Manager of Boulder, reports that the coal-tar enamel lining in service eight years was in perfect condition when it was recently examined.

The City of Greeley, Colorado, obtains its water from a source in the mountains and brings it to Greeley through a transmission line about 40 miles long. Some of this transmission line traverses very active soils. The accompanying table gives the analysis of soil samples at various points along the transmission line.

You will note that the SO₄ in all of these soil samples was very high. The soil is so active, in fact, that on a five-mile stretch of carefully made

cylinder concrete pipe, in many places it completely disintegrated the 2½ inches of concrete on the outside of the steel cylinders in nine years. For a number of years now the City of Greeley has had several miles of 27-inch diameter steel pipe in operation in these same soils. The pipe has a wall thickness of 3/16 inch and is coated inside and outside with coal-tar enamel. Roy Seaman, water works superintendent of Greeley, has examined the coating on this line very carefully over the years that it has been there. He reports that there is no action whatever on the coal-tar enamel coating. He also reports that the enamel lining inside of the pipe, where he has had occasion to tap the pipe in several places, is in perfect condition.

The City of Grand Junction, Colorado, has very active soil. An analysis of this soil can be found in volume 17, page 784, of the *Journal of Research* of the National Bureau of Standards. A report of the Bureau's

Water Soluble Salts in Soil—Parts Per Million

	Total Solids	SiO ₂	Fe ₂ O ₃ Al ₂ O ₃	Ca	Mg	SO ₄	CO ₃	HCO ₃	Cl	Na+K
G-21.....	1212	29	20	217	16	699	0	89	22	0
G-22.....	3230	24	17	192	225	1682	0	132	24	0
G-23.....	1208	23	23	37	4	920	0	55	20	0
G-24.....	3036	16	12	590	54	1443	0	48	16	121
G-25.....	2442	15	10	623	10	1172	0	78	22	141
G-27.....	2914	29	16	595	94	1596	0	78	18	126

findings relative to the corrosion of various types of material may also be found in this volume of the *Journal*.

The City of Grand Junction does not have any coated pipe in its water system. For that reason, no comparative data on the life of coated and uncoated pipe are available from the Water Department. However, the gas distribution system of that city is made up of various types of pipe and of pipe with different types of coating. Some very good information was gathered from Charles Rump, manager of the local office of the Public Service Company of Colorado; and further information was received from D. J. Miller of the Denver office.

The gas distribution system of Grand Junction was installed in 1904 and consisted principally of cast-iron pipe. On account of the severity with which corrosion attacked this pipe, the company started testing various types of pipeline protection several

years ago. The first such test was begun in 1926. About 200 feet of cast-iron pipe was installed in a bed of sand which had been saturated with coal-tar paint. After this 200 feet of pipe was laid, coal-tar paint and sand were alternately poured over the top of the pipe to a thickness of about one inch. Recently this experimental section of pipe was dug up and examined. It was found that the pipe which had been coated in this manner was in perfect condition, while the uncoated pipe adjoining it was practically disintegrated.

In 1927 the company installed some 1½-inch and 2-inch service pipes which were made of steel and coated with about 1/16-inch of asphalt, applied hot. Some of these service pipes are reported to have failed within three or four years, and a few of them are still in service.

In 1928 some service pipes were installed which were coated with a grease type of protective coating.

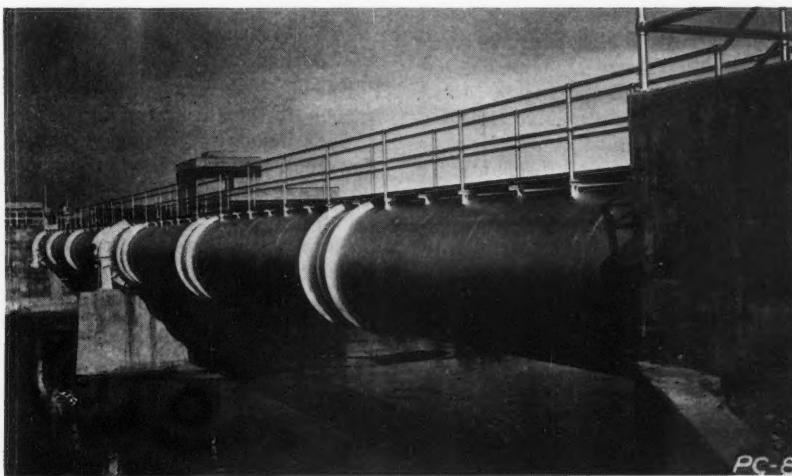


Figure 3—78-Inch diameter self-supporting line across Platte River.

Bad luck was experienced with these service pipes in just a few years.

In 1930 and 1931 another type of coating on service pipes was tried. This coating consisted of coal-tar primer, coal-tar enamel, and impregnated asbestos felt. To date Mr. Rump reports that after 16 years of service this type of protective coating has given perfect results.

The City of Los Angeles has perhaps had more experience with the use of coal-tar enamel for pipe protection than any other city in the United States. Their experience has been so successful that several years ago they installed their own coating plant. They do all of the enamel coating of their own pipe in this plant.

In 1937 the City of Denver installed a 78-inch diameter steel pipe to carry raw sanitary sewage across the Platte River to the sewage treatment plant. This pipe had a centrifugally cast coal-tar enamel lining to protect it from action of the sewage. (See Figure 3.)

Charles A. Davis, sanitary engineer for the City of Denver, has personally examined the inside of this steel pipe several times since its installation. I would like to quote the following from a letter recently received from him:

"You will be interested to know that I have recently made a personal examination of the inside of the 78-inch self-supporting steel pipe sanitary sewer across the South Platte River at the Denver Sewage Disposal Plant, designed and constructed by your company, construction having been completed November 15, 1937, and put into service December 1, 1937.

"This particular sewer flows from less than one-half to two-thirds full and carries not only domestic sewage but wastes from stockyards, packing plants, laundries, creameries, oil stations and small industrial plants generally. It also carries storm drainage from the wholesale commission house district and is at times subjected to considerable rough usage due to the fact that large tin containers, boxes and crates of all character, bottles of all sizes, large pieces of wood, bricks and other insoluble material are discharged into the sewer through manholes or otherwise.

"The inside of this steel pipe sewer was coated with a spun coal-tar enamel to an average thickness of 0.3/32-inch at the time of installation, and my recent examination failed to disclose deterioration of any character (breaks, cracks or otherwise) in the coating; also the coating showed no thin spots, only a highly polished surface was evident, which incidentally adds to the carrying capacity.

"No corrosion of the steel is evident, either inside or outside of the pipe.

"Due to the alignment of this sewer (southeasterly to northwesterly) the steel pipe is subjected to wide variations in temperature throughout its cross-section. The lower half has a fairly uniform temperature due to the constant sewage temperature, while the upper half on the south side is subjected to the direct rays of the sun throughout the entire day. The north side is shaded all day and subjected to our coldest winds. This temperature condition does not seem to have affected either the pipe or the inside coating."

The coal-tar enamel lining in this Denver sanitary sewer installation is subjected to a much more severe test than it possibly could be subjected to in the usual water pipe service. The sewage contains acids and releases gases which are very destructive to a great many materials. This installation is being watched with interest by sanitary engineers because it may offer a new type of pipe for sewage use; that is, steel pipe coated inside and outside with hot applied coal-tar enamel. Leakage into and out of sewers as now constructed not only contaminates the adjacent ground but throws a heavy load on sewage treatment plants due to infiltration of ground water. Steel pipe, being water tight, would eliminate both of these evils.

Let's digress a moment from water pipe installations and examine the record of an oil pipeline in Oklahoma and Texas, which was installed in 1926 and 1927 and which was dug up in 1942 and 1943 and reinstalled as part of a supply line in South Texas. The accompanying picture shows the condition of the surface of the pipe after the coal-tar enamel was sledged off. (See Figure 4.) In its 225 miles of length this pipeline traversed all kinds of soil conditions, some of them severely corrosive. After 16 years of service the pipe was reinstalled with its original coating, except for the places where the coating had to be knocked off so that it could be cut into lengths for shipment. The coating on this oil pipeline was subjected to the same severe corrosive conditions as is the coating on a water pipeline installed in similar soil.

The New England Water Works



Figure 4—Close-up of pipe where 16-year-old coating was sledged off for cutting out the old acetylene welds. Condition of the pipe is excellent, no corrosion, no pitting.

Association has perhaps done more research in connection with determining coefficients of flow of pipelines than any other organization in the country. Elson T. Killam, hydraulic and sanitary engineer of New York City, is chairman of that association's committee on Friction Coefficients. Mr. Killam recently called attention to an article in Volume 36 (1942), of the *Journal of the New England Water Works Association* written by J. O. Carpenter, of Gannett, Eastman and Fleming, Incorporated, Harrisburg, Pennsylvania, and George M. Rhoades, Jr., superintendent of Panther Valley Water Company, Lansford Pennsylvania. This article is interesting because it reports on flow tests made while the pipe was new and a similar test made after the pipe was eight years old.

The article quotes as follows:

"During the year 1932, a steel pipeline 10 miles long with an inside diameter of 30 inches was laid in a rather rugged territory, in Schuylkill County, Pennsylvania. Flow

tests conducted in 1935 over a period of three hours gave coefficients up to 145.8.

"The first five miles of the line were laid down the side of the Little Schuylkill River Valley, crossing a number of streams and many hills and gulleys. The second half of the line follows, for the greater part, the state highway, paralleling the Panther Creek Valley, where the grades were much easier and the bends fewer. On the whole line there were 83 special horizontal bends with a maximum curvature of 70 degrees, 40 minutes, and a minimum of four degrees, four minutes. There were 80 vertical bends with a maximum of 40 degrees, 36 inches. These bends were built of $\frac{3}{8}$ -inch steel plate, welded usually in four or five sections with a center radius of six to 10 feet.

"On November 17, 1940, after eight years of continuous service, this pipeline was again tested and the coefficient of friction was found to be between 144 and 145.

"Our conclusions are, therefore: (1) There has been no perceptible change in the Williams and Hazen coefficient 'C' since the line was installed eight years ago. (2) Unless something unforeseen happens to the lining, the coefficient is not expected to change in the near future. (3) For design purposes a value of 'C' equal to 140 can be used safely."

Now for the conclusions, which can be drawn from a study of the pipe installations referred to, located in various parts of the United States.

It is quite evident that steel water pipelines, properly coated with coal-tar enamel, will have long life and high carrying capacity. Economy may be gained with perfect safety by having the walls of these pipelines relatively thin. It has been demonstrated by usage that bad soils which may attack other types of pipe will not attack the coal-tar enamel coating on steel pipes. It is safe to conclude that long lines, such as the Texas oil line mentioned, can be protected against electrolysis by coal-tar enamel coating. Flow tests show that coal-tar enamel-lined pipe has the same carrying capacity after several years of service that it had when it was new. Because of this, it is evident that algae and other growths do not build up on coal-tar enamel surfaces as they have done on other types of pipe surfaces. Therefore, the high carrying capacity in coal-tar enamel-lined pipe remains permanent with age instead of diminishing. Because the surface of the enamel remains permanently smooth, enamel-lined pipe can be expected to have a carrying capacity equal to, or greater than, that of other types of smooth interior pipe. Lastly, it seems that the conclusion of Messrs. Carpenter and Rhoades, in their article regarding the Panther Valley Water Company's pipe, is conservative when they conclude that "for design purposes a value of 'C' equal to 140 can safely be used" in Williams and Hazen formula for the design of coal-tar enamel-lined steel pipe.

Disadvantage of Dissimilar Metals in Equipment

By T. G. Hieronymus

Kansas City Power & Light Company, Kansas City, Missouri

An Open Letter to Manufacturers

WHY on earth do you continue to do it when you know better and know that the results are going to be disastrous? Is it because you feel that the quicker the device wears itself out, the quicker you will have an opportunity to sell a new one?

Now that I have that off my chest, perhaps I had better elucidate. Very seldom does one find a machine or device of any magnitude that does not have dissimilar metals in contact. Of course the great majority of these devices are very seldom, if ever, used in a location and under conditions such that the dissimilar metals will react electrolytically and produce corrosion. But that is not true in many other instances.

For example: We have two deep well pumps at one of our generating stations. Not long ago one of them was pulled out of the ground and the shaft was found to be eaten a third of the way toward the center. The construction was of a series of bronze impellers shrunk on to a steel shaft supported on bronze bearings, and the electrolytic action had eaten away the steel where it was exposed.

There are several ways in which that condition could have been obviated but I doubt whether the man in the design room of the pump company had ever had any contact with the users of the pumps, espe-

cially after the pumps had been in service for a number of years so he could be made conscious of the necessity for eliminating such conditions.

Another instance is a case of some heat exchangers, where copper pipes were welded into a steel shell and operated with pipes half in and half out of distilled water and steam, with the inevitable results.

After many cases of trouble, we discontinued the use of galvanized cable hangers and copper weld messengers for supporting aerial lead-covered cable. We just dipped the hangers in lead; thus the part that was important, the lead sheath of the cable, was in contact only with a similar metal and all pitting of the lead sheath from electrolytic action was stopped.

On page 63 of the April 27, 1946, issue of *Electric World* is an article entitled "Corrosion of Watthour Meters in Ocean Beach Areas." Photographs and text give plenty of data on the way dissimilar metals and reliance on paints have caused trouble. I quote one phrase from the text: "Recently manufacturers' representatives were sent from the factories to get first-hand information on corrosion problems. In every case they expressed surprise that action was so severe." Thus again we see that the designers are seldom aware of the actual conditions that their

brain child may have to face.

One of the really large scale examples of backward thinking is evidenced in this city by the requirement that all water services have to be made of copper pipes, which are in turn fastened to a steel pipe main, the idea apparently being that copper is less subject to corrosion than steel and therefore should last longer. Naturally electrolysis is no respecter of metal, and where electrolysis is responsible for the destructive action the copper is eaten away just as fast as steel would have been. In fact, failure often occurs sooner because the copper pipe is thinner than the steel pipe would have been.

On page 9 of the December, 1945, issue of *Corrosion and Material Protection* is a photograph of a magnesium alloy airplane wheel that was badly corroded because of the use of two dissimilar metals.

I could go on and on reciting examples, but it would just waste your time and do no good if the idea isn't already apparent that definite consideration should be given to the inadvisability of the promiscuous and

indiscriminate use of dissimilar metals.

There are many manufacturers' representatives present at this convention, and there may be others who will read this article when it is printed. My only hope is that you will take the message back direct to your designing department and impress upon those in the departments where the ideas and designs are first hatched the importance of giving consideration to possible corrosive action.

The fact that the two adjacent dissimilar metals are covered over with a nice shiny coat of paint before the device leaves the factory doesn't mean a thing. The designer must visualize the conditions under which the device will be working, not the day it is first installed but five, ten or more years after installation.

If just one manufacturer will take heed and control his designs so that they will minimize corrosion on his products and gain for himself a reputation for putting out corrosion-free equipment, then this paper will not have been written in vain.

Yours for less corrosion.

Condenser Tubes of Aluminum Alloys

By R. B. Mears

Head, Chemical Section, Development Division, Aluminum Company of America,
New Kensington, Pennsylvania

CONDENSER tubes of aluminum or its alloys have been used to some extent for over 25 years. The use of aluminum tubes has been limited by four main factors. These are:

1. Lack of knowledge regarding the chemical properties of aluminum which make the use of aluminum tubes desirable in certain cases.
2. Fear that cooling waters would prove corrosive to aluminum tubes.
3. Belief that aluminum tubes were expensive compared to tubes of competitive materials.
4. Fear of galvanic corrosion resulting from contact of aluminum tubes with tube sheets, headers, or shells made of other materials.

At the present time in most cases none of these limiting factors is justified.

Chemical Characteristics of Aluminum

Aluminum and many of its alloys have several chemical characteristics which fit them for use in condenser and heat exchanger tubes. As a class, they are highly resistant to oxidation and do not form heavy scale when heated in air or in contact with oxidizing substances. They are also resistant to many organic chemicals even at elevated temperatures and in the presence of water, sulfur compounds, ammonia or carbon dioxide. This high resistance to sulfur com-

pounds and ammonia is probably the attribute which has resulted in the greatest use of aluminum tubes. Aluminum is also resistant to certain inorganic chemicals; notably concentrated nitric acid, hydrogen peroxide, boric acid, chromates and most substantially neutral salts of the alkali or alkaline earth metals.

The aluminum alloys such as 2S, 3S, 52S, and 61S (See Table I) are highly resistant to distilled water (1) and to many natural waters. Cases are known where condenser tubes of 2S or 3S have been used continuously for 10 to 15 years without appreciable corrosion resulting. Waters which are substantially neutral (pH 5 to 8) never cause rapid general attack of aluminum alloys 2S, 3S, 52S, and 61S even at temperatures up to the boiling point. However, some waters may cause appreciable localized pitting attack. For this reason, while condenser tubes of these alloys may give highly satisfactory service in certain plants or localities, they cannot be generally used at plants all over the country. An alclad alloy, Alclad 3S (2), which is resistant to localized attack, is now being marketed.

Alclad 3S

By way of background it appears desirable to discuss some of our experiences with Alclad 3S (3). Alumi-

num teakettles fabricated from sheet have been used for several generations. Generally they proved to be entirely satisfactory. However, in certain locations the local waters caused pitting of the teakettles which occasionally resulted in perforation. Tests were conducted at the Aluminum Research Laboratories which resulted in the development of Alclad 3S. This duplex product has a central core of 3S with a coating of another aluminum alloy (72S) on one or both sides of the 3S core. The coating alloy is bonded metallurgically to the 3S core over the entire surface and is, in fact, integral with it. A photomicrograph of a section through a sheet of Alclad 3S is shown in Figure 1. The coating alloy is selected so that it will be anodic to the 3S core when exposed to natural waters or most substantially neutral solutions. This means that, if an area of Alclad 3S sheet is exposed to

a water which is sufficiently corrosive to start a pit in the sheet surface, once the pit has penetrated the coating, it will not extend deeper into the core. Instead, it will broaden out parallel to the surface. Attack into the core will not occur until all of the coating has been removed from a large area. This normally requires a very extended period of time.

In tests made at the Aluminum Research Laboratories, using a highly corrosive water, the time to perforation of an Alclad 3S specimen ranged from eight to 60 times as long as was required for a similar specimen of non-clad 3S alloy.

Alclad 3S Teakettles

On the basis of these laboratory tests, several hundred Alclad 3S teakettles were made and tried out in service all over the United States. The results were remarkable. In the

TABLE I
Compositions and Typical Mechanical Properties of Some Aluminum Alloys

Alloy	COMPOSITION*	Temper	MECHANICAL PROPERTIES				Average Coefficient of Thermal Expansion Per Degree Fahrenheit Temp. Range 68-212 °F.
			Tensile Strength psi	Yield Strength psi	Elongation Percent in 2 Inches	Thermal Conductivity at 100° C. C.G.S. Units	
2S	Commercially Pure aluminum	O	13,000	5,000	35	0.54	0.0000133
		1/2H	17,000	14,000	9	0.52	
3S	1.2% manganese	O	16,000	6,000	30	0.45	0.0000133
		1/2H	21,000	18,000	8	0.38	
52S	2.5% magnesium 0.25% chromium	O	29,000	14,000	25	0.37	0.0000130
		1/2H	37,000	29,000	10	0.37	
61S	0.25% copper 0.6% silicon 1.0% magnesium 0.25% chromium	O	18,000	8,000	22	0.41	0.0000130
		W	35,000	21,000	22	0.37	
		T	45,000	39,000	12	0.37	
Alclad 3S	A duplex product consisting of a central core of 3S with a coating of 72S on one or both sides.	O	16,000	6,000	30	Approx. same as For 3S	Approx. same as For 3S
		1/2H	21,000	18,000	8		
		H	29,000	25,000	4		

* Aluminum and normal impurities constitute remainder.

succeeding four years, not a single Alclad 3S teakettle was reported as having been perforated by corrosion. Since then a total of over 250,000 Alclad 3S teakettles have been made, and only five of these were reported as perforating as a result of corrosion in a period of over four years. These kettles were used all over the United States in contact with all types of waters.

In many homes a teakettle receives very hard service, since it is frequently never allowed to stand

dry, but is always at least partly filled with water. Often a substantial percentage of the water is allowed to boil away, thus subjecting the kettle to the action of waters much more concentrated in solids than was the initial water used to fill the kettle. It is believed that this experience with Alclad 3S teakettles has a definite relationship to the expected performance of Alclad 3S condenser tubes.

Alclad 3S Fuel Tanks for Aircraft

Aircraft fuel tanks are also subjected to severe conditions of service. In the first place they are made in relatively thin gauges, since weight is of great importance. In the second place contaminated waters, called sump waters, are always present as a separate phase at the bottom of the tank. The fuels themselves never appear to be directly corrosive to the tanks, although constituents of the fuels may dissolve in the sump water and add to its corrosiveness. The exact source of the sump water is still the subject for debate. However, its presence and range of compositions are well established. Sump waters always contain chlorides, bromides, and compounds of iron, copper and lead. They are generally slightly acid in reaction. The range of compositions is rather great, but there are generally at least 100 parts per million of chlorides or bromides (or both), and this may reach 1000 parts per million.

The effect of the sump water on a fuel tank depends to a considerable extent on the design of the tank. A tank which is designed so that it drains freely, permitting the sump water to be drawn out periodically

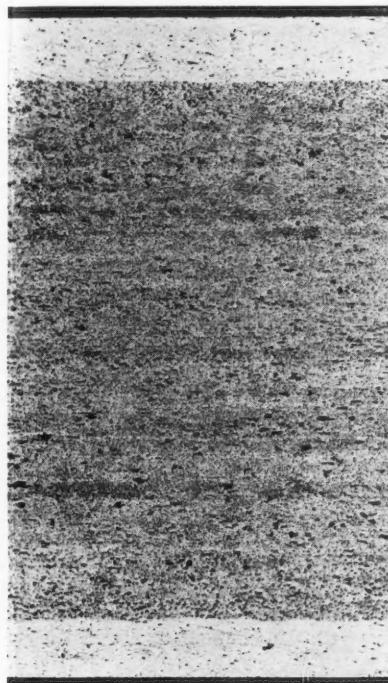


Figure 1—Etched cross section of Alclad 3S sheet at magnification of about 100x. The 72S coating is the lighter band on each side of the 3S core.

through the sump drain, generally suffers far less corrosion than one which cannot be drained adequately. In one type of aircraft where corrosion was particularly pronounced because of tank design, the American Airlines (3) conducted a service test with various types of tanks. They found that tanks made of 3S had a service life of about 3000 flying hours, while tanks of Alclad 3S sheet were still in good condition after 15,000 flying hours. This again points to the high resistance of Alclad 3S to perforation, even by waters known to be highly corrosive.

Alclad 3S Tubing

The tests and service results described above were all conducted with products made from Alclad 3S sheet. A typical example of a test with Alclad 3S tubing is shown in Figure 2. The Alclad 3S tube in this test was prepared by placing a 72S tube inside of a 3S tube and drawing them down together. No metallic bond between the coating and the core existed in this case. This Alclad 3S tube was pulled into an aluminum condenser, all the other tubes of which were of 3S. This Alclad 3S tube outlasted two successive sets of 3S tubes and was finally removed in good condition when the entire condenser was retubed with Alclad 3S tubes.

It is particularly interesting that, while the coating alloy in this tube had been perforated by corrosion at numerous areas, the 3S core had been completely protected by the coating. Less than 10 percent of the coating had been consumed by corrosion. Since the coating electrolytically protected the core, it seems

probable that a rather high percentage of the coating would have to be consumed before the core would be attacked. To be conservative, we might assume that 50 percent of the coating would have to be consumed before there would be insufficient coating left to protect the core. At the same rate of attack as occurred during the test on this tube, a period five times as long as the test period would be required. Since this Alclad 3S tube already lasted twice as long as 3S tubes, it would be reasonable to estimate that Alclad 3S tubes would last 10 times as long as 3S tubes in this location.

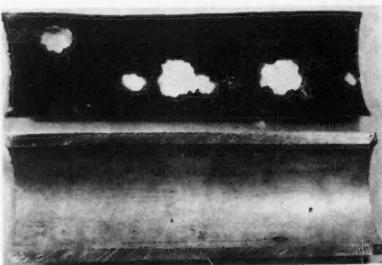


Figure 2—Longitudinal section through an Alclad 3S condenser tube which outlasted two successive sets of 3S condenser tubes. The Alclad 3S tube in this test was prepared by placing a 72S tube inside of a 3S tube and drawing them down together. Since no metallic bond was obtained by this method, it is possible to remove the 72S coating when the tube is sectioned. In this picture, the 72S coating has been removed from the 3S core. Note that although the 72S coating is perforated by corrosion, no appreciable attack has developed even in exposed areas of the 3S core. This is an excellent demonstration of the electrolytic protection afforded by the 72S coating to the 3S core.

EDITOR'S NOTE: An enlarged view of this picture appears on this month's front cover.

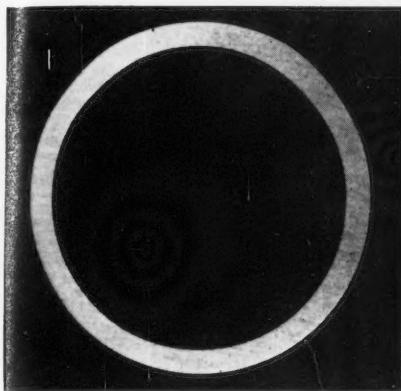


Figure 3a—Unetched cross section of Alclad 3S tube at a magnification of about $1\frac{1}{2}X$. The 72S coating is not visible.

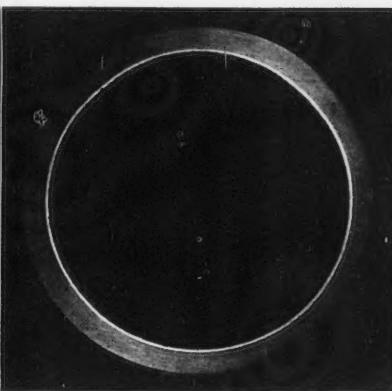


Figure 3b—Etched cross section of the same tube shown in Figure 3a. Etching has made visible the 72S coating on the inside of the tube.

Several trial applications of Alclad 3S tubing were made. In all cases it proved highly resistant to the cooling waters used.

Alclad 3S tubing can also be made in which the 72S coating is bonded metallurgically to the 3S core. Photographs at low magnification of sections through such tubing are shown in Figure 3. Figure 3a is a photograph of a polished section through the tubing. It will be noted that the entire thickness of the tubing looks homogeneous and, in fact, cannot be distinguished from a similar section through a non-clad 3S tube. Figure 3b shows a similar section of an Alclad 3S tube which has been etched to make the coating visible.

This Alclad 3S tubing can be handled just as if it were ordinary 3S tubing. In fact, it is generally impossible to distinguish between the two materials by the way they respond to forming, threading, expand-

ing or any ordinary mechanical treatments.

Since it is known that Alclad 3S is much more resistant to the development of deep pits by natural waters than are the non-clad aluminum alloys, and since non-clad aluminum alloys have been used to a considerable extent for condenser tubes, it is reasonable to expect that Alclad 3S condenser tubes will be widely employed in the future. Already several hundred thousand linear feet of alclad tubing have been used for condenser tubes or similar applications involving exposure to various types of waters, and in no case have any difficulties from corrosion been reported.

Cost of Aluminum Tubing

Thus, from a purely technical standpoint, aluminum alloy tubing, especially Alclad 3S tubing, shows high promise for condenser tube use. It is of interest to consider the relative cost of aluminum alloy tubing

TABLE II

Mechanical Properties of Aluminum Alloy Tubing

Alloy	Outside Diameter Inches	Wall Thickness Inches	Wall Gauge Stubs & BWG	Approximate Weight in Pounds Per Linear Feet	Max. Internal Working Pressure in psi			Max. External Working Pressure in psi		
					O	½H	H	O	½H	H
2S	$\frac{1}{2}$	0.065	16	0.104	877	1230	1754	340	925	1350
		0.049	18	0.082	644	901	1288	260	675	980
	$\frac{3}{4}$	0.065	16	0.164	564	789	1128	220	580	835
		0.049	18	0.127	417	585	834	165	415	580
	1	0.065	16	0.224	415	581	830	165	415	575
		0.049	18	0.172	308	432	616	115	280	375
	$1\frac{1}{2}$	0.083	14	0.434	350	490	700	135	330	455
		0.065	16	0.344	271	380	542	100	235	305
		0.049	18	0.263	203	284	406	65	145	180
	2	0.083	14	0.59	259	363	518	95	220	285
		0.065	16	0.464	201	281	402	65	145	180
		0.049	18	0.353	151	212	302	45	80	80
3S	$\frac{1}{2}$	0.065	16	0.105	1170	1520	2120	405	1175	1595
		0.049	18	0.083	855	1113	1553	305	850	1140
	$\frac{3}{4}$	0.065	16	0.166	750	974	1360	265	730	970
		0.049	18	0.128	555	722	1008	195	515	665
	1	0.065	16	0.226	552	718	1002	180	510	660
		0.049	18	0.174	410	534	745	140	340	420
	$1\frac{1}{2}$	0.083	14	0.438	465	605	846	160	390	510
		0.065	16	0.347	353	469	655	115	275	340
		0.049	18	0.266	270	351	490	80	165	190
	2	0.083	14	0.596	345	448	626	110	260	310
		0.065	16	0.468	268	347	486	75	165	190
		0.049	18	0.356	201	262	365	50	80	80
52S	$\frac{1}{2}$	0.065	16	0.102	2104	2680	2980	925	1835	2225
		0.049	18	0.081	1542	1961	2197	675	1305	1570
	$\frac{3}{4}$	0.065	16	0.161	1350	1718	1922	580	1110	1320
		0.049	18	0.125	1000	1273	1420	415	765	875
	1	0.065	16	0.220	995	1267	1418	415	745	870
		0.049	18	0.169	739	939	1051	280	475	530
	$1\frac{1}{2}$	0.083	14	0.426	840	1069	1193	330	575	655
		0.065	16	0.338	650	826	925	235	380	415
		0.049	18	0.258	486	618	694	145	190	190
	2	0.083	14	0.581	620	790	884	220	345	385
		0.065	16	0.456	481	611	685	145	190	190
		0.049	18	0.347	362	452	515	80	80	80
61S					O	W	T	O	W	T
					1318	2541	3262	535	1350	2400
					965	1868	2380	400	980	1675
					845	1633	2084	345	835	1415
					626	1210	1548	255	580	930
					624	1203	1540	250	575	920
					463	895	1140	180	375	555
					525	1015	1294	210	455	695
					406	786	1010	150	305	440
					304	589	750	100	180	190
					388	752	958	140	285	395
					302	583	744	100	180	190
					226	439	559	60	80	80

(Continued)

compared with tubing of other competitive materials. Probably more tubing of $\frac{3}{4}$ -inch O.D. is used for condenser tubes than any other size. From recent quotations it appears that, at present, the cost per linear foot of tubing of this diameter and 0.040-inch wall thickness is definitely less for aluminum alloys 2S and 3S than for ordinary seamless steel tubing of equal wall thickness.

As the diameter of the tubing, or its wall thickness, increases, the relative difference in the cost of aluminum alloys 2S and 3S as compared to that of seamless steel also decreases. For tubes of large diameter or heavy wall thickness, seamless steel tubing costs less per linear foot than does tubing of these aluminum alloys.

Alclad 3S tubing costs about 30 percent more than does 2S or 3S tubing. Thus, for the smaller diameters and wall thicknesses, the cost of Alclad 3S tubing per linear foot is about the same as that of seamless steel; but for larger diameters or wall thicknesses, the seamless steel tubing costs less.

Of course, these cost relationships may alter at any time so that the above discussion can serve only to indicate approximate relationships.

Mechanical Properties of Aluminum Tubing

Table II gives the weight per linear foot, maximum internal working pressures, and maximum external working pressures of various aluminum alloy tubes. Tubes of 2S have the lowest maximum working pressures, while tubes of 61S-T have the highest maximum working pressures. Alclad 3S tubes have maximum working pressures similar to those of 3S. Data on the strength of aluminum alloy tubes at elevated temperatures are given but not at temperatures below room temperature. However, for all aluminum alloys thus far investigated, they are the same as or higher than the strength at 75° F.

Engineering Considerations in Using Aluminum Condenser Tubes

Aluminum condenser tubes are especially well suited for use in contact with vapors containing ammonia, hydrogen sulfide, or carbon dioxide, since most aluminum-base materials are highly resistant to these chemicals either alone or in combination. In condensers where the cooling water flows through the tube interiors, it is generally desirable to use Alclad 3S tubes, unless

TABLE II (Continued)

ALLOY	CONVERSION FACTORS				
	75° F.	200° F.	300° F.	400° F.	500° F.
2S-O.....	1	0.8	0.58	0.46	0.27
2S-14H.....	1	0.86	0.77	0.56	0.20
2S-H.....	1	0.88	0.73	0.25	0.14
3S-O.....	1	0.85	0.69	0.50	0.16
3S-14H.....	1	0.90	0.86	0.67	0.50
3S-H.....	1	0.93	0.79	0.59	0.36
52S-O.....	1	0.88	0.79	0.62	0.41
52S-14H.....	1	0.90	0.81	0.60	0.35
52S-H.....	1	0.98	0.83	0.63	0.32
61S-T.....	1	0.93	0.69	0.42	0.14

NOTE: (1) The values given in this table for maximum internal working pressures are based on a factor of safety of 4 and a temperature of 75° F. To determine the maximum internal working pressures at elevated temperatures, multiply the pressures given in the table by the following conversion factors. These temperature conversion factors do not apply in the case of external pressures.

(2) Alclad 3S tubing is approximately the same in weight per linear foot and in maximum internal working pressure as 3S tubing.

it is known that 2S or 3S tubes are not attacked by the particular cooling water being used. If the cooling water contacts the exterior surface of the tubes and some vapor is being condensed or cooled on the tube interiors, it is generally of no benefit to use Alclad 3S tubes, since the alclad coating can be applied only to the tube interiors at present. In such cases 2S or 3S tubes are satisfactory for certain waters without any special protection. In an additional class of waters, 2S or 3S tubes can be used provided their exteriors are cathodically protected (4) by zinc or aluminum-zinc alloy attachments to the interior of the condenser shell or elsewhere. In certain waters cathodic protection in this manner is not effective, and it is not at present feasible to use aluminum tubes unless these waters can be treated economically with suitable corrosion inhibitors (5).

Since in all waters thus far studied, aluminum is definitely anodic to copper-base alloys, it is generally not suitable to use aluminum tubes in contact with copper-base alloy tubes, tube sheets, headers or shells.

Aluminum alloy tubes have been used successfully in contact with cast iron or steel tube sheets, headers, or shells. In certain waters, the aluminum tubes will be cathodic to iron or steel parts in contact with them, and thus the tubes are actually protected at the expense of the ferrous parts. In other waters, little or no galvanic action occurs between the iron or steel and the aluminum, and in still other waters the aluminum tubes are definitely anodic to the ferrous parts and suffer appreciable galvanic attack. Waters containing substantial concentrations of

dissolved chlorides are those most likely to stimulate galvanic attack of aluminum parts in contact with iron or steel.

Therefore, in the absence of specific information, it is generally desirable to avoid contact between ferrous parts and aluminum parts on the water side of a condenser. However, if such contact is unavoidable, undesirable galvanic effects on either the iron or the aluminum parts can usually be prevented by employing zinc or aluminum-zinc alloy attachments to protect cathodically the other two metals.

Aluminum alloy tubes can be expanded into tube sheets in the same manner as tubes of other materials. Other methods of attachment, such as welding or the use of bushings, are used in special cases.

The mechanical strength of aluminum alloys decreases rather rapidly at temperatures above about 300° F. (See Table II). It is generally not feasible to use aluminum alloy heat exchanger tubes above about 500 to 500° F. for this reason. In some cases aluminum linings have been used in steel tubes at temperatures up to 900° F. In such cases the aluminum linings protected the steel from the action of corrosive substances passing through the tubes, while the steel supplied the required strength.

Summary

Condenser tubes of aluminum alloys 2S and 3S have been used to some extent for the past 25 years. Certain cooling waters, which may be highly corrosive to tubes of ferrous materials or other non-ferrous alloys, have little action on the aluminum alloy tubes. Other waters

may cause localized pitting. Tubes of Alclad 3S are much more resistant to pitting attack by corrosive waters than are tubes of aluminum alloys 2S and 3S. Laboratory tests and limited service experience indicate that Alclad 3S tubes will resist perforation by corrosive waters for periods from 4 to 10 times as long as 2S or 3S tubes. Thus, Alclad 3S condenser tubes offer definite promise in solving many corrosion problems.

The cost of Alclad 3S tubing per

linear foot is about the same as that of seamless steel for tubes of smaller diameter and is slightly higher than that of seamless steel for larger or heavier tubes.

At the present time, Alclad 3S tubing is produced with the alclad coating on the inside surface of the tubes. Thus, Alclad 3S tubing is adopted for use in condensers where the cooling water flows through the tubes but is not especially advantageous if water contacts the tube exteriors.

References

1. H. V. Churchill, Ind. & Eng. Chem., Analyt. Ed. **5**, 264, 1933. H. V. Churchill, Chem. & Met. **46**, 226, 1939.
2. U. S. Patent No. 1,997,165.
3. Data supplied through the courtesy of Mr. G. K. Brower.
4. R. B. Mears & H. J. Fahrney, Trans. Amer. Inst. Chem. Eng. **37**, 911, 1941.
5. G. G. Eldredge & R. B. Mears, Ind. & Eng. Chem. **37**, 736, 1945.

EDITOR'S NOTE: It is the policy of the Publications Committee and of CORROSION to eliminate insofar as possible all use of brand names, trademarks and other references which might be regarded as "advertising," and which would refer only to a specific product of an individual manufacturer. There are many terms which, through wide usage, are becoming grafted onto the vocabulary of technology, and which in time will merit a place in the dictionary as now do "Bessemer" or "Diesel." Many of these terms are appropriated by industry, and the specific product name is used to refer to all similar products. This is especially true when the brand name is short, easily remembered, and takes the place of an involved phrase or sentence. For these reasons, no attempt has been made to translate the easily understood "Alclad" into a descriptive phrase, and any advertising accruing to the manufacturer is incidental.

1946-47 Directors of N.A.C.E.

With the Board of Directors now at full strength, as provided by the Articles of Organization, National Association of Corrosion Engineers, there are 22 directors, some of whom may be known to many of the Association members, but others whose acquaintance may be limited to some group or area, and who therefore are strangers to most of the membership. To introduce these directors to the membership, CORROSION is carrying brief biographical sketches of the present Board, supplementary to the sketches run on the officers in the June issue. Due to space limitations, it was impossible to complete the roster of directors in this issue. The sketches of the remaining members of the Board are scheduled for the October number.

L. A. Baldwin, Vice President in charge of the Industrial Department, Johns-Manville Sales Corporation, was born in Seneca, Kansas, on March 23, 1890. He graduated from the University of Kansas in 1912. Before joining Johns-Manville in 1920 as a salesman, he had wide experience with oil and utility companies in Kansas. From 1920 to 1922

he was manager of the construction department of Johns-Manville's St. Louis office and for the next three years was in the oil industry department of the St. Louis office.

He has done considerable development work, including experience with evaporation saving devices and materials for pipe protection, for the oil industry. Some other Johns-Manville posts which he has held include manager of the sales engineering department, eastern division, 1929; manager general sales engineering department, general headquarters, 1930-1933; staff manager, power products and industrial department, general headquarters, 1934-1941. He was appointed to his present post in 1942. He has two daughters and resides at Greenwich, Connecticut. He is a director representing associate memberships.

Robert B. Mears, Head of the Chemical Section of the Development Division of the Aluminum Company of America, was born in Scranton, Pennsylvania, in 1907. He was graduated from the Pennsylvania State College in 1928 with a B. S. degree in Electrochemical Engineering. From 1928 to 1932 he was employed at the Bell Telephone



L. A. BALDWIN

Laboratories in New York City, where he worked on electroplating and corrosion problems. At the time he left, he was leader of the Corrosion Testing Section. He studied at Cambridge University in England from 1932 to 1935.

After obtaining a Ph.D. in Metallurgy, he returned to America as a Research Engineer in the Aluminum Research Laboratories in New Kensington. He spent 10 years at these Laboratories, ultimately becoming Chief of the Chemical Metallurgy Division. While at Cambridge, Dr. Mears held a Carnegie Scholarship. Since that time, he has been active in many technical societies, including the Electrochemical Society, the American Society of Refrigerating Engineers, the American Institute of Chemical Engineers, and the American Society for Metals. He

has published several papers on corrosion and its prevention. He is Chairman of the Technical Practices Committee of N.A.C.E. and is a member of the Executive Committee.



H. B. BRITTON

H. B. Britton, Chief Engineer, Plantation Pipe Line, was born November 8, 1895, at Ewing, Ill. He was educated in Illinois, graduating from the University of Illinois in 1924 with a B. S. in Engineering.

He married Miss Margaret Campbell in 1924. Mr. Britton joined Shell Oil Company in 1925 and worked in various engineering capacities through early 1941. He joined Plantation Pipe Line as Chief Engineer during the construction days in 1941 and has continued in this capacity. He is a Director of N.A.C.E., representing the Southeastern Region.



ROBERT B. MEARS



FRED L. GOLDSBY

Fred L. Goldsby, Research and Development Engineer, Chicago Bridge & Iron Company, was born in June of 1903 at Flora, Illinois, the center of the Southern Illinois oil fields. He was graduated from the University of Illinois in 1927 with a B. S. degree, and became associated with the Chicago Bridge & Iron Company immediately thereafter. His career began in the shop and continued in the drafting room, field, and engineering department.

His present position is that of Research and Development Engineer, engaging him in engineering problems involving the products of his company, which include special steel plate structures, elevated water tanks, oil storage and refinery vessels, pressure vessels such as Hortonspheres, Hortonspheroids, pipelines, etc. His hobbies are photog-

raphy and gardening. Mr. Goldsby is a director representing corporate memberships.

George B. McComb, Manager of the Protective Coating Sales, The Barrett Division, Allied Chemical & Dye Corporation, was born in Virginia 53 years ago. He lived in Western Pennsylvania during his early life. A graduate engineer, he has spent most of his business life in the development and sales of products used in technical fields. He has been with Barrett more than 20 years and has been identified with the development of their underground pipe protection work. He has an active part in many of the national trade and technical associations. Mr. McComb is Chairman of the Regional Management Committee of N.A.C.E.



GEORGE B. MCCOMB

Stephen P. Cobb, Consulting Gas Engineer, Ebasco Services Incorporated, is a native of Michigan. He graduated from the University of Michigan in 1901 and became associated with the gas industry in 1904.

After working for various gas companies in operating and engineering departments, he became associated with the engineering staff of Electric Bond and Share Company in 1914. He has been with that company and its successor, Ebasco Services Incorporated, continuously since then. He is now Consulting Gas Engineer for Ebasco. Mr. Cobb's interest in corrosion problems lies primarily in the protection of underground steel structures, and he has done a large amount of work on the protection of underground steel pipe. He is Chairman of the Policy and Planning Committee of N.A.C.E.



STEPHEN P. COBB



HUGH J. McDONALD

Hugh Joseph McDonald, Director, Corrosion Research Laboratory, Illinois Institute of Technology, was born in Glen Nevis, Ontario, Canada, on July 27, 1913. His formal education included Queen's University, McGill University (B. S., 1935), and Carnegie Institute of Technology (M. S., 1936, D. Sc., 1939). He married Margaret Taylor in 1942 and has one son. Dr. McDonald joined Illinois Institute of Technology, Chicago, in 1939 and has progressed from Instructor to Professor. He has served as Director of Corrosion Research Laboratory since 1944.

He is a Registered Professional Engineer, Illinois. Dr. McDonald received competitive scholarship, Royal Society for Advancement of Science, 1933-34; Sigma Xi Research

Award, 1944; American Society for Metals Research Award, 1944; and American Academy of Arts and Science Research Grant, 1945. He is active in several technical and professional societies and at the present time is serving as Secretary-Treasurer of the American Coordinating Committee on Corrosion and as Vice-Chairman of the Corrosion Section of the Electrochemical Society. Dr. McDonald is a Director representing the Central Regional Division of N.A.C.E.

Glenn W. King, Sales Engineer, Brance-Krachy Co., Inc., was born January 16, 1911, in El Paso, Texas. He attended Rice Institute, Houston, Texas, taking a B. S. Degree in Mechanical Engineering in 1935. He

joined Brance-Krachy immediately after graduation.

Mr. King and his wife, the former Miss Frances Kennard, share several hobbies which include hunting, fishing, golf, and various handicrafts. His ambition is to become a gentleman farmer. During World War II Mr. King served as a U. S. Naval Reserve Officer in the Navy Inspection Service. He is a Director in N.A.C.E. representing corporate members.



GLENN W. KING



ROBERT POPE

Robert Pope, member of technical staff, Bell Laboratories, was born in Brooklyn, New York, on March 8, 1899. He was educated in public schools and at Stevens Institute of Technology, Hoboken, New Jersey, where he received the degree of Mechanical Engineer in 1920. He was

employed by the Long Lines Engineering Department of American Telephone and Telegraph Company in 1920 and was transferred to the Department of Development and Research in 1924. That department was merged with Bell Telephone Laboratories in 1934. He has been interested in corrosion problems on underground cables since 1920, and is now doing development work on new methods for detecting and preventing such corrosion. His hobby is photography. He married Ruth Dorothy Edling on July 26, 1922. They have one son, Robert Charles, who is attending Lehigh University. Mr. Pope has served on the Board of Directors of N.A.C.E. since its inception, and at this time is representative of the Northeastern Regional Division and is a member of the Executive Committee.

F. L. LaQue, Head of Corrosion Engineering Section of Research and Development Division of International Nickel Co., was born in Gananoque, Ontario, Canada, in 1904. He attended the public and high schools in that town and completed his formal education at Queen's University at Kingston, Ontario, Canada, with a degree of Bachelor of Science in Chemical and Metallurgical Engineering.

Shortly after graduation, Mr. LaQue joined the staff of the Development and Research Division of The International Nickel Company in New York City. After preliminary training in the company research laboratory at Bayonne, New Jersey, and the mill at Huntington, West Virginia, Mr. LaQue was assigned to work on corrosion-resist-



F. L. LAQUE

ant alloys. He has continued in this field of activity.

From 1937 to 1939 Mr. LaQue served as Assistant Director of Technical Service; from 1940 to 1945 he had a general assignment in the Development and Research Division. In 1945 Mr. LaQue was placed in charge of a newly organized Corrosion Engineering Section of the Development and Research Division.

Mr. LaQue has been active in connection with matters relating to corrosion in numerous technical societies. He has served as chairman of the Gibson Island Corrosion Conference of the American Association for the Advancement of Science, and was chairman of the American Coordinating Committee on Corrosion in 1944-1945. He is a director representing active members.

Corrosion Abstracts

ATMOSPHERIC CORROSION

Resistance of Copper Alloys to Atmospheric Corrosion. A. W. TRACY, American Brass Co. Paper before A.S.T.M., Symposium on Atmospheric Exposure. Tests on Non-Ferrous Metals, Pittsburgh (1946) Feb. 27, A.S.T.M. Preprint (1946), 17 pp.

Correlation and discussion on data on copper alloys, upon reaching the 10-year mark of A. S. T. M., exposure tests on corrosion of non-ferrous metals and alloys, by Committee B-3, Sub-Committee VI. Corrosion was measured at eight exposure sites having industrial, marine and rural atmospheres of various types. Determination of weight changes is reported and loss by weight and loss in t.s. compared. Full graphs and tables. Conclusions were: Tough-pitch copper, phosphorus deoxidized copper, silicon bronze, tin bronze, red brass, copper-nickel-zinc alloy and copper-nickel-tin alloy may be used interchangeably as far as resistance to outdoor atmospheric corrosion is concerned. None of the alloys tested revealed any evidence of intergranular corrosion during the first 10 years of the test. Highly alloyed brasses, such as high-tensile brass and 70/30 brass, are subject to intergranular attack when internal stresses are present. Admiralty metal was more resistant than 70/30 brass, but is not

as free from danger of season-cracking in the atmosphere as some of the higher copper alloys.

BEARING CORROSION

Bearing Corrosion—I, II and III. H. H. ZUIDEMA, Shell Oil Co. Oil and Gas J., 44, No. 41, 100+ (1946) Feb. 16; 44, No. 42, 151+ (1946) Feb. 23; 44, No. 43, 66+ (1946) March 2.

Comprehensive survey of literature and data from investigations by Wood River research laboratories of Shell Oil, with discussion on all phases of bearing corrosion. Tables include: (1), Summary of compounds claimed in U. S. patents as bearing corrosion inhibitors; (2), corrosion of various bearing materials in Underwood test at 325°F. in presence of metallic copper; (3), relative corrodibility of different bearing metals in existent corrosivity and thrust bearing corrosion tests; (4), comparison of connecting-rod bearings in a passenger car engine at 300°F. base oil temperature; (5), comparison of coarse and fine-structure copper-lead bearings; (6), bearing corrosion tests, listed and described; (7), effect of temperature on bearing weight loss in diesel engines using copper-lead bearings; (8), effect of lacquer film on bearing corrosion of copper-lead bearings. In the test of various bearing metals in presence of metallic

cooper at 325° F., all four babbitts were practically inert in comparison with alkali-hardened lead, copper-lead, cadmium-silver, and cadmium-nickel. The first two were roughly equivalent with cadmium-silver more reactive by a factor of four, and chromium-nickel by a factor of six. Bibliography lists 42 references.

BOILER CORROSION

Metallizing Gives Turbine New Lease on Life. H. M. Atwood, Metallizing Co. Power, **90**, No. 1, 109 (1946) Jan.

Over a period of 23 years, wet steam eroded the housing and diaphragm ribs of a turbine until it was no longer serviceable. In these areas, and where strength of the parts was not a factor, a coating of 0.025-inch of 18-8 stainless steel was applied to arrest erosion. How this was done is described in detail with illustrations. At a cost of less than \$215, equipment costing over \$60,000 and irreplaceable at time of spraying, was restored to service.

Treating to Prevent Scale Introduces Carryover Problem. E. M. GRIFFITHS, Republic Steel Corp. Paper before Engrs. Soc. of Western Penna. 5th Ann. Water Conference, Oct. 31, 1944. Power, **90**, No. 1, 88-91, (1946) Jan.

Treatment of the three raw-water sources making up the feedwater at the Youngstown Republic Steel Plant, included a supplemental disodium phosphate treatment within the boiler to avoid heavy sludge in drums. Drums were also redesigned. Flow sheet is shown and full details of water treatment are given.

Intercrystalline Corrosion of Pre-heater Tubes. W. MANTEL, Zeitsch. Ver. deutsch. Ing., 88, April 29, 1944, 238-240. Mond General Refer. Sheet, Ser. No. **465**, 9 (1946) Jan. 19.

Metallographic study of peculiar cracks developing in preheater tubes of open hearth steel (St. 35.29), which could not be accounted for by normal causes, indicated that traces of oxygen, or of an oxygen carrier in the water flowing through the preheater, had caused oxidation of the tube surfaces. The protective oxide formed eats into the surface; local stress variations, due to non-uniform heating and cooling, expand the tubes, resulting in breaking away of the oxide layer in strips or in a reticulated film. The fine cracks formed are transverse to the direction of main stress and permit penetration of oxygen into the metal surface, leading to wider cracks. Further variations in stress promote further penetration of the oxygen and progressive spread of the corrosion. There is a good series of photomicrographs illustrating the nature of the damage progressively occurring.

Condenser Tube Corrosion. R. MAY, Corrosion Investigator, Brit. Non-Ferrous Metals Research Assoc. Marine Eng'g & Shipping Rev., **51**, No. 1, 138 (1946) Jan.

The writer comments on article by A. C. Rohn, "Engineering Developments on Maritime Commission Vessels" (same magazine, May, 1945, p. 165-170) and offers British experience with corrosion of condenser tubes. Zinc protector plates are never used in Britain, mild steel being used instead. Zinc protectors become stifled by a layer of corro-

sion products, resulting in the prevention of alloy tubes from undergoing the initial attack necessary for forming of natural protective film. A cathodic film is formed instead, which is non-protective and interferes with the formation of the protective film when the zinc plates stop working. If this happens while tubes are undergoing violent air-bubble impingement, attack gets ahead of film formation; and high-grade alloys may fail badly. The risk in relying on cathodic protection is pointed out. A high proportion of failures is associated with partial obstruction of tubes (e.g., by shell-fish), causing intense local impingement, and interfering with protective currents reaching points in the wake of obstruction. In condensers designed for high water speed, the utility of electrolytic protection is problematic, since it would not make conditions safe for ordinary tubes, and would tend to prevent formation of the fully protective films on high grade alloys.

Scaling of Some Metals in Pure Steam. W. BAUKLOH AND F. FUNKE, Korrosion und Metallschutz, **18**, No. 4, 126-130 (1942).

Experimental data on scaling resistance of iron, nickel, copper, zinc and cast iron (gray and white) in steam and in dry air are presented. In contrast with the behavior of iron, the scaling resistance of nickel is greater in steam than it is in air. When exposed to steam, copper shows only minute signs of scaling, up to a temperature of 1,000° C. Pure zinc offers about the same resistance in air as it does in steam. The surface of the pure metal un-

dergoes marked passivation. Results obtained on Armco, as well as on gray and white iron, are presented. Scaling resistance of white cast iron is at all temperatures better than that of gray cast iron. The particular form in which the graphite is present in cast iron, therefore exerts a decisive influence. A cast iron with large graphite flakes, which are interconnected, will put up greater resistance to the action of steam and to rapid scaling.

A Note on Corrosion—Effect on Sectional Hot Water Boilers. W. PERCIVAL and J. J. AGGIO, Chem. Age (London), No. 1381, 564, **53** (1945).

The expected 15 years' life of cast iron sectional hot water boilers has not been achieved in the Leicestershire district with direct coal firing, due to excessive external corrosion caused by chlorides in the fuel. Use of coke and anthracite is preferred, and the convenience of mechanical stoking with slack, etc., must be carefully considered where salt is in the fuel.

More Information Concerning Corrosion in Steam-Heating Systems. L. F. COLLINS, Proc. Ann. Water Conf. Eng. Soc. Western Penna., **4**, 33-51 (1943), J. of the Inst. of Metals & Metall. Abs., **13**, 13-14 (1946) Jan.

The corrosion rate was found to be proportional to the amount of carbon dioxide passing through the experimental apparatus in unit time. No practical method of preparing carbon dioxide free steam from carbonate feed water is known. In experimental condensers the equilibri-

um concentration of carbon dioxide was obtained in the condensate water in 100-500 minutes, the highest carbon dioxide concentration being found in the gas phase closest to the condensate. In corrosion tests using condensate, copper alloys were corroded at less than half the rate of bessemer steel; aluminum, tin, stainless steel, and Inconel showed practically no attack.

Special Studies of the Feed Water—Steam System of the 2000 psi Boiler at Somerset Station of the Montauk Electric Company. W. D. BISSEL, B. J. CROSS, AND H. E. WHITE, ASME preprint, Paper No. A-45-58, (1945) Nov. 1.

During the course of an investigation of the high pressure forced circulation boiler, a study was made on the feed water and steam system, with regard to the dissolution of iron throughout the system and the formation of high iron sludges within the boiler. The dissolution of copper was also studied. Possible source of the latter was Monel condenser tubes.

Inhibitor of the Corrosion of Metals in Contact with Water and/or Steam. M. MURRAY, Steam Engineer 15, 117 (1946) Jan.

The following suggestions are offered:

In cooling and heating systems, correct acidic tendencies; and (1), in closed systems use sodium sulfite to deoxygenate; (2), in open systems add chromate.

In boiler feed water systems pH should be high, and hexametaphosphate added for stabilizing calcium salts. In boilers keep pH above 9.6,

avoid deposits, deaerate if necessary.

In steam and condensate lines corrosion may indicate priming and carry over, leaks, or collecting and standing of condensate in low places.

Amines and Corrosion Control. G. CORSARO, Sci.—Eff.—Ec. Laboratories, Inc., National Eng. 50, 122 (1946) Feb.

Mechanism of condensate corrosion is discussed showing the inevitable presence of carbon dioxide. Addition of amines to neutralize carbonic acid is discussed. Choice of amine is based on four properties: (1), The amine added to the boiler water, even in shots at intervals, must escape with the steam and condense with the condensate near the same temperature as water; (2), the amine must raise the pH value of the condensates with few P.P.M. present in the condensate; (3), the amine must not in itself be corrosive once present in the steam and condensate; (4), the amine must escape uniformly in the steam. Tests indicate that a cyclic secondary amine is required.

CATHODIC PROTECTION

Magnesium Gives High Cathodic Protection to Pipe Lines and Buried Structures. L. M. OLDT, Dow Chem. Co., Nat. Petrol. News, 38, No. 10, R-186-R-187 (1946), March 6.

By the use of magnesium anodes, a steel piling driven 14 feet into earth, at the Dow Chemical Company's Freeport plant, which was expected to withstand corrosion for five years, now has life expectancy over an indefinite period. Composition of a special magnesium alloy for this purpose is given. High cur-

rent efficiency is realized and the rate of local corrosion is reduced to a minimum by controlling the copper, nickel and iron content. This is, respectively, maximum 0.05, 0.003 and 0.003. Installation of anodes is also described.

Cathodic Protection of Stainless Steel Surgical Instruments with Aluminum-Foil Wrap. J. A. CALAMARI. Modern Packaging, **18**, 125, (1945) Feb. Mond. Gen. Refer. Sheet Ser. No. 463, 9, (1946) Jan. 5.

Cleaned, dried, and oiled instruments are wrapped in bright aluminum foil and heat-sealed in a suitable envelope. Any corrosive action which may occur is cathodically directed toward the aluminum envelope. The method described has been developed by the U. S. Army Medical Department.

Magnesium for Cathodic Protection of Pipe Lines. ROBERT M. HUTCHISON, Houston Natural Gas Corp. Petroleum Engineer, **17**, No. 6, 213, 216-218 (1946) March.

Details are given relative to the use of magnesium electrodes for protecting a natural gas line. Owing to the high resistance of the soil, a special backfill was used around the electrodes.

Although this article has been confined to the discussion of the work done on a gas transmission line, this is by no means the only application of this type of cathodic protection. Installations have been made on steel piling, storage tanks and other metal structures subject to electrolytic action, with varying degrees of success. The writer wit-

nessed installations and was particularly interested in one method that employed a special electrolytic and ceramic jar. In this case the rod is placed inside the jar, the electrolyte poured around the electrode, and both sealed inside with a cap through which the electrode wire protrudes. The developers of this method, for which a patent application has been made, claim a higher efficiency of current output, ease of installation and maintenance, and a more constant rate of current discharge. These jars are also especially adapted to tank protection because the jars containing the rod and electrolyte can be lowered into a tank, regardless of its liquid contents, and then will provide greater protection with the use of a minimum amount of magnesium.

It is also likely that the small cost of installation will make the use of the rods practical for spot protection of old pipelines and distribution systems. For example, it may prove advantageous to install rods wherever pin holes or evidence of electrolysis have been found in order to arrest or eliminate future trouble at these hot spots. Such a course simplifies the practice in the case of transmission lines and no doubt will do likewise in distribution systems; but in some instances it will be necessary to install insulators in service lines if full benefit is to be obtained on the mains.

As a matter of fact, the entire proposition is comparatively new, and there is still much to learn; but as results have been highly satisfactory thus far, it appears that the practice should be continued.

CHEMICAL CORROSION

Corrosion of Metals and Alloys in the Tanning Industry. A. H. WINHEIM, International Shoe Co., and R. A. MILLS, Endicott Johnson Corp. Report by Am. Leather Chem. A soc., Chemical Engineering Committee. J. of Am. Leather Chem. A soc., 441-478, (1945) Dec.

Corrosion resistance of 1729 test specimens representing 56 different metals or alloys was carried out in 11 different plants in various locations. Technical advice was furnished by Inco. Metals, and alloys tested included nickel, Inconel, Ni-Resist, Illium G, Durimet, various types of stainless, low alloy steels, Hastelloy A and C, and cast-iron. A Monel spool-type specimen holder was used. Full data are tabulated for all parts of the process and equipment. A flow sheet is provided.

The Corrosive Action of Benzole Absorption Oils. C. M. CAWLEY and H. E. NEWALL. J. of the Soc. of Chem. Industry, **64**, No. 10, (1945) Oct.

An account is given of a laboratory investigation carried out at the fuel research station of the Benzole Technical Committee of the Ministry of Fuel and Power, with the object of determining the nature and origin of the substances causing corrosion in benzole absorption plants. It was concluded, as a result of the work, that the main cause of corrosion is the action of ammonium thiocyanate, which is formed, at least in part, by the reaction between ammonia and carbon disulphide in solution in the wash oil. The deposits of Prussian blue, often found in benzole

absorption plants, are apparently formed by reaction between ammonium thiocyanate and iron.

Corrosion of Several Special Steels in Mud. V. ROMONOVSKY. Compt. Rend. **219**, 185-6, (1944).

Polished plates of six percent nickel, 25 percent nickel, 46 percent nickel (platinite), 18-8 chromium-nickel, 19-7 percent chromium-nickel, 17 percent chromium, 13 percent chromium and ordinary steels were partially or alternately immersed in fresh water or marine mud. All special steels were stainless in sea water and when completely immersed in marine mud, but were corroded severely when partially or alternately immersed. All the special steels were stainless in fresh water mud and performed much better than ordinary steel. Steels containing nickel were better than the straight chromium steels, 18-8 performed badly, while platinite performed well even under unfavorable conditions. The upper surface of the mud, on which a red film resembling aerobic bacteria formed, was most corrosive.

Recent Russian Work on Corrosion: Chemical Apparatus and Halogen Compounds. Ts. A. ADJEMYAN. Paper before Second Conference on Corrosion, Moscow, 1943. Mound General Refer. Sheet, Ser. No. **464**, 13, (1946) Jan. 12.

Work done at the State Institute of Applied Chemistry, Leningrad, in the period 1938-40, to test the corrosion-resistance of different materials employed in the construction of apparatus for the basic Russian chemical industries, is described. Special attention is devoted to the behavior

of metals and other materials in evaporation processes, and in the manufacture of sodium salts; nickel, nickel alloys, Monel, and Nichrome steels figured prominently in the materials tested, and gave satisfactory results, e.g. the Nichrome steels gave good resistance to gaseous hydrofluoric acid at 300-500°.

The Role of the Inhibitor on the Fixation of Hydrogen by Polycrystalline Iron During Acid Cleaning. L. MAREAU. Compt. Rend. **218**, No. 9, 353-355, (1944).

Organic inhibitors (as 2 percent pyridine) added to acid cleaning baths containing hydrochloric acid, 10 percent sulfuric acid or 10 percent nitric acid in alcohol are absorbed intergranularly by iron and prevent intercrystalline absorption of hydrogen. Hardness and bend tests of exposed specimens show increase of mechanical properties of polycrystalline iron cleaned with inhibitor present is identical to that of a single crystal attacked by the pure acid.

Isopentane Produced by Liquid-Phase Isomerization. L. S. GALTSAUN, Tide Water Associated Oil Co. Chem. and Met. Eng'g, **52**, No. 9, 109-111, (1945) Sept.

The Tide Water pentane isomerization unit, first commercial plant of its kind, is described. No corrosion protection is needed in vessels and lines in pentane service, and where pentane, catalyst (anhydrous aluminum chloride and anhydrous hydrogen chloride), complex and hydrogen chloride must be handled together. Carbon steel is satisfactory except where turbulent conditions

exist, or in equipment such as motor and block valve where no corrosion is tolerated. The contactor, a turbulent zone, is of nickel-clad steel. All valves in catalyst service are of Hastelloy trim. Stress relieving of large vessels or pipe in catalyst service is standard, since thermal or mechanical stresses in steel used in this service generally cause aggravated corrosion.

Corrosion Reporter — Handling Acetic Acid. Chem. and Met. Eng'g, **52**, No. 9, 209-210, (1945) Sept.

Extensive use of stainless steel 18-8 for glacial acetic acid is discussed. For other concentrations, lead pipes are used, since concern is not for handling food; and attack is not extensive enough to warrant expense of other materials. Corrosion at cold end of distilling pipes is explained. Use of a few feet of silver pipe at critical point solved problem.

Corrosion of Copper by Sodium Chloride Solutions. R. DUBRISAY and G. CHEESE. Compt. Rend., **220**, No. 20, 707-708, (1945).

Corrosion cannot proceed without oxygen, but the presence of carbon dioxide is unnecessary. Tests in sea water, and sodium chloride solution, proving this, are reviewed, and the reactions involved are cited.

Marine Corrosion and Erosion. J. W. DONALDSON. Metal Treatment, **12**, No. 43, 159-170, (1945) Autumn.

Review of reports and articles from U. S. and Britain on marine corrosion, particularly anti-fouling studies, since 1940. Tables include those from the Sea Action Corrosion

Committee of the Institute of Civil Engineers on corrosion of various metals, including 3.75 nickel steel, in various British ports; and vibratory tests on materials including Ni-Resist, Monel and special copper-nickel alloys, as well as low-nickel bronzes. Cavitation erosion investigations are included. Bibliography.

Danger in Dairy Utensils and Apparatus from Aluminum. H. WOLF. Chem. Zeit., **68**, 45-47, (1944). J. of the Inst. of Metals and Metall. Abs., **12**, 203, (1945) June.

A review and discussion of corrosion possibilities of the light metals used in dairying.

Corrosion Reporter—Materials Used at Rahway Plant of Merck & Company. Chem. and Met. Eng'g, **52**, No. 12, 195, (1945) Dec.

This company produces small amounts and a great variety of extremely pure chemicals, so that equipment not only must be highly corrosion resistant, but also able to withstand all of the different products. For work at any temperature or concentration of nitric acid, 18-8 molybdenum and KA₂SMo stainless steel are used. The latter has been exposed continuously to boiling nitric acid for 15 months without sign of corrosion. For more corrosive reactions with hydrochloric acid, stuffing boxes with Hastelloy sleeves are used. Hastelloy is also employed to pipe cold material. Tantalum is the only metallic material satisfactory for a mixture of acetic and hydrobromic acids, and is used in packing column supports. No metals except tantalum are used in contact with either alcoholic hydrobromic or

alcoholic hydrochloric acids. Stainless gives excellent performance in handling chlorinated solvents, which constitute a borderline case where plain steel is almost but not quite satisfactory. Valve trim must be stainless, and stainless is economical for storage tanks. Stainless and aluminum are used interchangeably in processing acetic acid. Aluminum is preferred for high-temperature work, as in stills and condensers, although it is not very satisfactory as a valve material.

Corrosion Reporter—Equipment for Food and Pharmaceutical Products. Chem. and Met. Eng'g, **52**, No. 9, 211-212, (1945) Oct.

Lead has been completely replaced by stainless steel in one plant where edible acids (citric, tartaric, gluconic and ascorbic) are manufactured. Type 316 is preferred. In a reducing environment or in the presence of sulphides, Type 316 is preferable to Monel. Otherwise stainless and Monel are used interchangeably to handle any concentration of these acids up to 120°C. Hastelloy C pumps are used with 35 percent hydrochloric acid. A stainless steel tank and agitator in a plant producing activated carbon were corroded to uselessness in very short order, and rubber-covered or lined steel is now used.

Bimetallic Double-Wall Tubing for Combating Corrosion. Product Eng'g, **17**, No. 2, 102-103, (1946) Feb.

Bimetallic tubing to withstand simultaneously two different types of corrosive attack is useful in heat exchangers, oil refineries, synthetic rubber manufacture, ammonia refrigeration systems, and chemical

plants. Metals and alloys that may be combined include steel, stainless steel, aluminum, Monel, Admiralty, copper, aluminum and aluminum-brass, Muntz-metal, bronze and copper-nickel. For oil refinery service and synthetic rubber manufacture, steel is used outside to resist corrosive oil vapor and copper inside toward the fresh water; steel outside toward the oil and Admiralty inside toward circulating salt water. Other applications call for combinations such as copper-nickel outside, red brass inside; stainless steel outside, aluminum or brass inside. Designs and methods of assembly to obtain tight mechanical contact, to provide for expansion and contraction of both tubes in low-pressure installations, and to avoid galvanic corrosion are discussed with drawings. Common tubing alloys are summarized briefly with corrosive agents each resists. Stainless and Monel are included.

Catalytic Effect of Metals and Light on Fats and Oils. N. W. ZEILS and W. H. SCHMIDT (Lever Bros. Co.). Paper before Committee on Food Research, Office of Quartermaster General, Conference on Problems Related to Fat Deterioration in Foods, June 20, 1945. Oil and Soap, 22, No. 12, 327-330, (1945) Dec.

Aluminum and nickel were the only metals among those tested found absolutely free of any pro-oxidant effect on hydrogenated vegetable oils during the deodorizing process. Inconel and Rezistal were the best of the alloys tested, while Monel was the poorest, probably because of its high copper content. Data regarding the behavior of two

boiler-plate steels and 18-8 and 18-8-3 stainless steels at 180°-230°C. are tabulated. The metal effect as a rule became more noticeable with increasing temperatures. The mechanism of the catalytic pro-oxidant action of metals is not entirely clear. While the preponderance of evidence points to metallic soaps as the most active catalysts, inorganic metal salts are also very active. Metals used were lathe turnings or 10-mesh granules, in no case in the powder form.

Corrosion Reporter—Treating Sulphonated Oils. Chem. and Met. Eng'g, 52, No. 9, 209, (1945) Sept.

Problem is that equipment is exposed alternately to acid and alkaline environment. Wash tank where acidified oil is dumped and excess acid is diluted and neutralized has wide range of pH. Monel, lead stainless steel, all failed. Best service is tank of cypress wood. Cooling coils inside tank of Monel or stainless frequently have to be replaced. Monel coils in sulphonating vessel failed miserably, but when heat-treated gave no trouble. Corrosion expert from government recommends Durimet 20 for this equipment. Sulphonating vessels themselves are lead-lined.

Corrosion Reporter—Motor Corrosion Trouble in Dye House. Chem. and Met. Eng'g, 52, No. 9, 212-213, (1945) Oct.

Hydrochloric and sulfuric acid fumes in a dye house attacked motors, especially agitator motors, which last from two to 10 years. The attack on copper starters is so severe that occasionally a ferrule

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type fuse has been pushed away from the fuse clip, loosening the clip and causing the motor to run single phase. Practical solution has been to use cadmium plated clips. Only final solution to motor problem lies in use of totally inclosed motors. Painting and baking are being used as temporary preventive measures.

Aluminum in the Chemical Industry. W. J. PASSINGHAM. The Mining J., **226**, No. 5762, 65-67, (1946) Jan. 26.

Advantages of the use of aluminum in the chemical industry are discussed briefly. Choice of aluminum or aluminum alloy, problems of joining, reaction of aluminum to water, steam, fluorine, chlorine, bromine, hydrogen peroxide, sulfur, sulfuric acid, and a few uses are discussed. A point worth noting is that while the majority of metals have colored salts, all aluminum salts are colorless, and, if only for this one reason, aluminum is often chosen when purity and color of product is important.

Corrosion by Hydrofluoric Acid. W. Z. FRIEND and H. O. TEEPLE, International Nickel Co. Oil and Gas J., **44**, 87 (1946) March 16.

Laboratory data are given for Monel, 70-30 copper-nickel alloy, copper-aluminum bronze, fine silver, carbon steel, nickel, Inconel, lead, stainless steel, Ni-Resist, Hastelloy B, and Hastelloy C in acid concentrations, varying from 10 to 100 percent with temperatures from 70° to 240°F. Data from test spools containing most of above metals, plus others in operating HF alkylation units and acid storage tanks, are

given. The character of attack of the various metals is discussed along with the effect of fluorosilicic acid as an impurity.

The Corrosion of Zinc from the Standpoint of the Battery Chemist. C. DROTSCHMANN. Batterien, **12**, 240-242, (1943); Chem. Zentr., **114**, No. 2, 2308, (1943). J. of the Inst. of Metals and Metall. Abs., **12**, 359, (1945) Nov.

A number of different corrosion processes which affect zinc and zinc alloys used in batteries are described. The action of pure acids and the influence of dissolved oxygen are discussed. Practical measures are given for providing protection against corrosion in the construction of zinc elements.

The resistance of Special Metals and Alloys to Mineral Acids. I. YA. KLINOV. Khim. Mashinostroenie, 1940, No. 11/12, 20-26 (In Russian). J. of the Inst. of Metals and Metall. Abs., **13**, 13 (1946) Jan.

Data are given which were obtained from tests on steels and a considerable number of copper, aluminum and lead alloys in sulfuric, hydrochloric, phosphoric, sulfurous and nitric acids.

Corrosion Reporter—Electrolytic Chlorine Production. Chem. and Metall. Eng'g, **53**, No. 1, 227-228, (1946) Jan.

Flow-sheet and description of typical American practice in production of electrolytic chlorine. Some materials of construction are listed. German production methods are mentioned. Sintered nickel powder filter tubes were used to remove carbon

particles from mercury cell liquors. Nickel, forced circulation evaporators were used in concentrating caustic. Eleven-ton cast-iron pots were employed to bring it to anhydrous condition. Since adopting vacuum operation, pot life has been increased from 100 to 250 charges.

COATINGS

A Study of Primers for Ferrous Metals in an Atmospheric Exposure—Progress Report No. 1. New England Club, Official Digest **250**, 393 (1945) Nov.

A five year program has been outlined. One thousand metal specimens are to be exposed. Exposures will be: (1), flat panels; and (2), duplicate set under as nearly practical conditions as possible. Flat panels will be six inches by 12 inches of 20-gauge plate steel. Panels will be solvent degreased and dip coated. Twelve-inch lengths of angle iron four inches wide and $\frac{3}{8}$ -inch thick will be used to represent practical conditions. These samples will be degreased, wire brushed and spray painted. Variation in pigment volume, film thickness, effects upon performance of application by brush, spray and dip will be tried. Both back and front side will be inspected. Specimens will be exposed at 45° facing south in a semi-industrial area near Boston.

The following will be evaluated: Red lead (95-97 percent), basic lead chromate, basic carbonate, basic carbonate and sulfate white lead, sublimed blue lead, metal-lead, lead titanate, titanium dioxide, basic lead silicate, normal zinc chromate, salt

free zinc chromate, zinc tetroxyl, zinc chromate, zinc dust, zinc oxide, red, yellow and black iron oxide, graphitic mica, aluminum powder, barium, calcium and strontium chromates. Various extenders will be used such as: magnesium silicate, mica, diatomaceous silicate. Other materials will include wetting agents, Vinylite copolymers, linseed oil, and oil extended phthalic alkyds and phenol-formaldehyde resins.

American Corrosion—Preventive Materials.

JAMES A. RICHARDSON, U. S. Army. Petroleum **8**, 29 (1945).

Corrosion preventives are defined as materials which are applied to unpainted metal surfaces for their protection, and which are removable with petroleum solvent to leave the surface in as good a condition as when the material was applied. These are classed as thick film type (usually petrolatum or mineral jelly bare), thin film types (compounds diluted with volatile solvent), and fluid types (mineral oils with corrosion inhibitor added). Specifications for a general description of above are given, together with a brief description and explanation of the control tests required to characterize each material.

Electroplating on Non-Conductor

A. H. STUART. Petroleum **8**, 25 (1945) Feb.

To electroplate a non-metal, it is necessary to obtain a conducting bonded film as the foundation, Research showed that very small (4-8 M) graphite oriented graphite particles gave a superior conducting film. One method of obtaining a film of 35 ohm resistance per unit area is

described. Prodag C (a colloidal graphite), manufactured by E. G. Acheson, Ltd., is suspended in a water solution of an emulsion (based on ceresol-formaldehyde known as Beckosol Emulsion 2354), and is brushed on with a soft brush and rubbed with a soft cloth to orient the graphite particles. This brushed film is dried at 110-130° C. The orientation may be obtained by drying object in a strong magnetic field. The dried film is insoluble in and impervious to water. It may be plated in an acid copper bath. Procedure for electroplating concrete to make it oil proof is suggested.

"Plastipitch" Protected Metal.
Railway Age, 120, No. 4, 231, (1946)
Jan. 26.

A new compound named "Plastipitch" for use on flat, corrugated or V-crimped sheet metal for roofing, siding, gutters, ventilators, flashings and ducts against highly corrosive atmospheres, particularly effective against smoke-laden atmospheres around railroad locations, is announced by Koppers Company. Steel sheets protected by this coating do not require further painting. The coating has permanent adherence at low as well as high atmospheric temperatures.

Corrosion-Resistant Coatings.
Electrical Manufacturing, 37, No. 1,
184, (1946) Jan.

Feature of a group of corrosion-resistant coatings (designated Alkacite), developed for a wide range of industrial uses, is the extremely small size of particles in the solid content—claimed to be only 0.001

micron. Unusually homogenous films and through penetration of the surfaces are said to result, with consequent effective protection against moisture, acid reaction, etc. Non-flaking and non-scaling characteristics of the films are cited for applications where conditions of extreme temperature changes are encountered. Electrical characteristics vary with the type of solvent used, but typical values show dielectric strength from 210 to 270 volts per mil, dielectric constant from 2.8 to 3.94, and power factor from 0.020 to 0.033 percent.

First Electrodeposition of Metal for Corrosion Resistance. S. G. BART, Bart Mfg. Co. Chemical Industries 58, 51 (1946) Jan.

Nickel or other metals are electrodeposited on the inside of random lengths of pipe and tubing approximately 20 feet long and from 2 to 18 inches in diameter. Specially designed anodes and plating machines make the process practical and efficient. A smooth, closely adhering deposit is obtained which will undergo heating, bending and reducing. By using a 25/20 chrome, nickel or Monel rod, successive lengths of pipe can be welded together to give a continuous corrosion resistant surface.

Nonferrous Metals Aid in Steel's Use. J. LEVIN (Bur. of Foreign and Domestic Commerce). Domestic Commerce, 33, No. 12, 37-40, (1945) Dec.

The role of non-ferrous metal coatings on steel is portrayed. General summary of use of tin, zinc, nickel, chromium and other metals that are plated, sprayed, or clad to steel is given.

Plastic Resins As Protective Coatings. P. O. BLACKMORE, Products Eng'g and Development Inter-chemical Corp. Product Eng'g, 17, No. 1, 1-7, (1946) Jan.

Applications, limitations and future possibilities of protective coatings formulated with liquid plastics are discussed. Alkyds, phenolics, ureas, melamines, vinyls, vinylidene chlorides, polystyrenes, and silicones are discussed from the standpoint of their utility in commercial finish formulations. Merits and most useful applications of each are given. Metal stampings and castings, including non-ferrous metal die castings, will use lacquers to a considerable extent, although the new speed-bake enamels will compete strongly for that market. The particularly good resistance to sea atmosphere of phenolic resin, and its use on structural steel in underwater applications, is mentioned. Among colored illustrations are examples of metal, coated inside and out with phenolic, alkyd or vinyl resins, and formed after finishing.

Corrosion of Steels. DR. JOHN JOHNSTON, U. S. Steel Corp., Corrosion and Mat. Prot. 3#3, 9-12 (1946) March.

This is an up-to-date discussion of the corrosion of steels, especially atmospheric corrosion, with a discussion of the value of certain alloying elements.

Non-metallic coatings as preventives of corrosion of steels: "By far the most important item in obtaining good protection of metal by a paint, or indeed, by any coating, is not the precise composition of the metal, but the proper preparation of the metal surface before the coating is applied.

All loose scale, preferably all scale, should be removed by suitable mechanical means, or by pickling where this is practicable. An inhibiting treatment may be of advantage; this is usually applied by immersing the steel in a solution containing a phosphate, chromate, cyanide, or some combination of these salts, though sometimes the solution is applied by spraying or brushing. All soluble material should be removed by proper washing, and the metal surface should be truly clean and dry when it is painted. A priming coat containing an inhibitive pigment, such as red lead or a chromate, is advantageous; but its use will not make up for lack of care in preparing the metal surface. For best results, painting should be done in a dry atmosphere on metal which is preferably warm. It never should be done when the metal is cold or wet, or even when the relative humidity of the atmosphere is higher than 70 degrees. Such conditions will lessen greatly the protective life of any paint or non-metallic coating. These statements serve to explain why the application of a paint by mechanical means on a freshly pickled and dried sheet, followed by subsequent baking, yields a product with superior resistance to corrosive attack.

"The useful life of a given paint, properly applied, is in general longest on Cor-Ten, somewhat less on copper steel, and much less on steels and irons of very low copper content. Some paints are far better than others when similarly applied. But the whole question of paints for metals is in a transition stage, and further experience will be required before definite comparative statements justifiably can be made."

This report is to appear in pamphlet form—U. S. Steel Corp.

Corrosion-Resisting Properties of Electrodeposited Tin-Zinc Alloys.
R. M. ANGLEE and R. KERR, Tin Research Inst. Engineering, 161, 289-94, March 29, 1946.

In the present investigation, corrosion tests on electrodeposited tin-zinc alloys of various compositions and thicknesses have been undertaken to determine the most suitable type of deposit for protecting iron and steel from rusting. A comparison has been made between the corrosion-resisting properties of tin-zinc alloys and those of electrodeposited tin, cadmium, zinc, and hot dipped zinc coatings. It is shown that, for a given thickness of coating, the greatest measure of protection is afforded by tin-zinc alloys containing approximately 78 percent tin. The effect of mechanical deformation on corrodibility has been examined, and it is found that the 78/22 tin-zinc alloy is able to withstand a reasonable amount of deformation by bending or cupping without appreciable reduction in protective value. The resistance of tin-zinc deposits to corrosive attack can be increased further by subjecting them to a chemical filming or passivating treatment. Particulars of several different filming solutions are given, and the results of corrosion tests on filmed products are briefly discussed.

By comparison with tin or zinc, electro-deposited tin-zinc alloys of suitable chemical composition possess certain outstanding advantages. As a means of protecting iron and steel against corrosion, tin-zinc is superior

to tin, zinc, or cadmium plate; and the protective value of the deposit, if necessary, can be further enhanced by subjecting it to a simple chemical filming treatment. Tin-zinc plating is also a comparatively simple process, and the deposits possess excellent polishing and soldering properties.

The chemical filming was realized by dipping in an alkaline phosphate-chromate bath, sometimes followed by a phosphoric acid dip, treatment in a cold phosphoric acid chromic acid dip, or the use of a warm phosphoric acid-chromic acid dip. An improved technique of dipping was developed, using chromic acid, warm or cold.

CONSTRUCTION MATERIAL

The Vital Importance of Corrosion in Freight Equipment. W. B. BROOKS (Alloys Development Co.), Corrosion & Material Protection, 2, No. 8, 21-24 (1945) Nov.

An analysis of the corrosion problems in freight equipment. Corrosion in hopper cars is largely atmospheric, and corrosion attack from sulfur compounds will occur only if cars are used to store coal some time. Lapped joints are a chief cause of corrosion and can be avoided by welding. "Cor-Ten" and use of copper steels in general for freight cars is discussed. The former gives excellent service and results in possible dead-weight savings in the order of six tons along with substantial increase in capacity.

Materials of Construction in a Metabisulphite Plant. G. S. WHEATON AND R. S. SUNDERLIN, Pittsburgh Chem. Co., Chem. & Met. Eng'g, 52, No. 11, 231-232, 234 (1945) Nov.

Flow sheet of process in produc-

ing of potassium metabisulphite shows materials of construction. Agitators are either stainless steel or lead coated. 18-8 molybdenum steel plays an important part and stands up much better than 18-8. Example is a pump of the former which lasted four years, whereas plain 18-8 wore out in one week. Heat exchanger is also 18-8 molybdenum as is saturator-crystallizer (jacketed). Slurry of potassium metabisulphite crystals is dropped into a centrifuge with a stainless steel basket. Wet crystals pass through a stainless continuous rotary dryer at 135° F. Plain steel parts are also described.

Electrolysis of Steel in Concrete.
A. E. ARCHAMBAULT, (N. Y. Central RR.), R. BEEUWKES (Chic. Milwaukee, St. Paul and Pacific RR.), and Others. Report before A.A.R. Elect. Section Eng'g Div., Dec. 5, 1945. Railway Mech. Engineer, 120, No. 1, 32-36, (1946) Jan.

In field tests between 1943 and 1945, steel electrodes encased in circular concrete forms of varying diameter, and in some cases further enclosed in iron pipe or surrounded with an asphalt coat, were placed in the ground and subjected to various amounts of current flow, the corrosive effects being noted. The electric potential maintained between the specimen and the ground resulted in surface deterioration of concrete of all uncovered specimens. Data are tabulated on the corrosion of the steel rods. Increasing the thickness of concrete reduced the rate of corrosion, but did not effectively eliminate it. Admixtures in concrete were not helpful, nor was the presence of a steel encasement effective. Asphalt

membrane waterproofing alone of all methods tried was effective in eliminating the corrosion of the steel and deterioration of concrete. Examination also was made of a concrete catenary foundation where a current flow of one to two amperes direct current accompanied train passage. Anchor bolts were subjected to corrosion proportional to that found in the test specimens.

Service Lives of Essential Parts in the Mechanical Plant Used in Sulphuric Acid Production. L. A. SMIRNOV, Khim. Mashinostroenie, No. 3, 14-18 (In Russian) 1939. J. of the Inst. of Metals & Metall. Abs., 13, (1946) Jan.

Data are given from 10 works regarding the service of cast-iron and steel parts of the plant for treating pyrites. Bronze bearings are also considered.

Electrolysis of Steel in Concrete.
The Engineer, 181, 205 (1946) March 1.

This is extracted from 1945 Reports of the Electrical Section, Engineering Div. of the Am. Assoc. of Railroads in *Railway Age*. The study of the electrolysis of steel in concrete was assigned to the research staff of the engineering division in 1943. Random Ferguson, electrical engineer, has been in charge of the tests and of preparing the report, under the direction of G. M. Magee, research engineer. The work is being carried on under the general supervision of a special sub-committee of the Committee on Electrolysis of the Electrical Section.

On the basis of observations, the committee has drawn the following conclusions:

(a) Increasing the thickness of concrete covering around reinforcing steel reduced the rate of electrolytic corrosion, but did not effectively eliminate it to prevent cracking of the concrete.

(b) Admixtures included in the test were not effective in controlling electrolytic corrosion.

(c) The presence of the steel covering reduced the rate of electrolytic corrosion, but did not effectively eliminate it, and resulted in some deterioration of the physical strength of the concrete.

(d) The asphalt membrane waterproofing covering of concrete provided an effective means of eliminating electrolytic corrosion of reinforcing steel and deterioration of concrete.

(e) The electric potential maintained between the specimen and the ground resulted in a surface deterioration of the concrete of all uncovered specimens subjected to direct current. The presence of some cinders, especially in the top portion of the sand and clay soil surrounding the specimens, may have been a factor in this deterioration; but this is a soil condition generally encountered near railway tracks.

Examination also was made of a concrete catenary foundation on the Illinois Central, where a maximum flow of one or two amperes direct current had been observed during the interval of train passage. The foundations had been in service 20 years, and subjected to this current for perhaps 10 percent of the total time.

While damage to the foundation did not indicate any need of repair, it was evident that the anchor bolts

were being subjected to corrosion, which is proportional to that found in the test specimens.

CORROSION TESTING

The Salt-Spray Corrosion Test.
G. T. DUNKLEY, Mechanical World, 118, 179-181, 192-195, (1945) Aug. 17, Bull. of the Iron & Steel Inst. No. 118, 150A, (1945) Oct.

The applicability of the salt-spray corrosion test for the following purposes is discussed: (1), Testing the porosity of cathodic coatings; (2), checking the thickness of anodic coatings; (3), estimating the life of a coating; (4), testing oxide and phosphate coatings; (5), examining paint and lacquer films; (6), determining the tendency of copper-zinc alloys to dezincification; (7), examining the behavior of two metals coupled together; (8), developing new alloys; and (9), testing zinc-base die-castings for their susceptibility to intercrystalline corrosion. The urgent need for a standardized salt-spray test is pointed out.

Coatings on Steel, Thickness Measurements with A. C. Solenoids.
S. LIPSON, Iron and Steel 19, 30 (1946) Jan.

Two instruments now used for measuring thickness of non-magnetic coatings are: (1), Brenner Magne-Gage, developed by the Bureau of Standards and manufactured by the American Instrument Co., based on strength of attraction to a magnet; and (2), an electromagnetic instrument manufactured by General Electric Co., which measures coating thickness by the amount the flux of a magnetic circuit is reduced by the coating, when it comes be-

tween the pole pieces of the core and the steel basis metal. A new coating thickness gauge is described, which employs the electromagnetic principle for determining the thickness of non-magnetic coatings on steel. Two models were constructed, which are referred to as "service model" and "research model." The question of the service model versus the research model is dependent on the accuracy desired. The coil is raised by hand on the service model and mechanically on the research model. For ordinary use the service model has the following advantages: (1), greater simplicity; (2), more rapid determination; (3), lower cost; and (4), voltage compensating feature.

Cavitation Testing and the Behavior of Metallic Materials Under Water-Hammer and Cavitation Attack. M. VATER, Korrosion und Metallschutz, **20**, 171-179, (1944) June, Mond Gen. Refer. Sheet, Ser. No. 463, 19, (1946) Jan. 5.

The essential mechanism of water-hammer and cavitation types of attack is discussed, and apparatus for cavitation tests is described. Tests on cast iron, cast carbon steels, 13 percent chromium cast steel, "special" brass and aluminum alloy are reported.

A Modified Salt Spray Test for Chromium Plated Zinc Base Die Castings. C. F. NIXON, GMC-Fisher Body Ternstadt Div., Am. Electroplaters Soc. Monthly Rev., **32**, No. 11, 1105-1108, (1945) Nov.

A modified salt spray test, using a solution containing one percent glacial acetic acid in addition to 20 percent sodium chloride, is more

satisfactory than the standard 20 percent salt spray test. Results correlate more closely with those obtained in actual service. Factors other than plate thickness, such as alloy composition, casting procedure, polishing, cleaning, and plating procedures, can be studied more readily in this test. The mechanism by which blister-like eruptions form is described, including progress through nickel and chromium coatings. Failures occur most readily in industrial regions and in winter. A table gives acid salt spray results for automobile parts plated to different thicknesses by ASTM Designation B86-43, containing four percent aluminum and three percent copper. A table also shows results of 1-year service on parts plated with various thicknesses of copper and nickel. Results emphasize the importance of plate thickness.

The Life of Steel Subjected to Alternating Test in Tap and Sea Water. M. VATER AND M. HENN, Korrosion und Metallschutz, **20**, 179-185 (1944) June, Mond Gen. Refer. Sheet, Ser. No. 463, 19, (1946) Jan. 5.

This article reports tests on steel with smooth and with notched surface, and has a discussion of the essentially similar characteristics of water-hammer and corrosion-fatigue attack.

Manual of Operation for Salt Spray Testing Equipment. H. P. TROENDLY, Borg-Warner Corp., Am. Electroplaters' Soc. Monthly Rev., **32**, No. 11, 1110-1114, (1945) Nov.

The combined experience at Borg-Warner Corp. and Rock Island Arsenal led to compilation of this manual of instructions for operat-

ing a salt spray cabinet. ASTM Designation B117-44T was heavily drawn upon. Recommendations by Production Engineering Sub-Committee of 0.50 Cal. Metallic Belt Link Committee are appended. Seven months of experience went into the preparation of the report.

Corrosion Criteria—Their Visual Evaluation. M. DARRIN, Mutual Chem. Co. of Am. Paper for A.S.T.M. A.S.T.M. Bulletin, No. 138, 37-39 (1946) Jan.

Standardized terms and procedures for describing and reporting various types of aqueous corrosion, particularly when of a localized nature, are suggested. A description of laboratory report forms and their use in obtaining and interpreting corrosion scores, chiefly by visual inspection, is included. Method has proved satisfactory over a period of 6 years.

The Behavior of Nickel and Monel in Outdoor Atmospheres. W. A. WESLEY, Inco, Bayonne, Paper before A.S.T.M., Symp. on Atmospheric Exposure Tests on Non-Ferrous Metals, Pittsburgh, Feb. 27, 1946. A.S.T.M., Preprint, 1946, 12 pp.

The present state of knowledge regarding the atmospheric corrosion of nickel and Monel is summarized. The mechanism of corrosion is described with respect to both the fogging and later stages of weathering. The effect of shelter from the rinsing action of rain is not pronounced. It is probable that the corrosion-time relationship is practically linear. Of the various methods for quantitative determination of amount of corrosion in field tests, measurements of loss of weight are

the most expedient for high nickel alloys. Chromium exerts a markedly beneficial effect when alloyed with nickel. Weight-loss data are presented graphically, with a discussion of engineering significance. Tables include relation corrosion rates of wire and sheet metal.

Apparatus for Evaluating the Corrosion - Resistance of Metals. G. O. TAYLOR, Canad. Machinery, 56, No. 2, 76, 124 (1945). J. of Inst. of Metals & Metall. Abs., 13, 14 (1946) Jan.

The apparatus is designed to provide a constantly and automatically changing point of drainage on every specimen under test. This eliminates the disadvantages of standard tests (such as salt-spray tests) in which it is difficult to provide a stable concentration of atomized mist over the entire interior of the apparatus.

FUNDAMENTALS

Potential Curves for Iron in Hydrochloric Acid. R. D. MISCH AND H. J. McDONALD (Ill. Inst. of Tech.), Corrosion and Material Protection, 2, No. 7, 17-20 (1945) Oct.

Experimental determinations at the Illinois Institute of Technology of potential-curves of iron for solutions of hydrochloric acid under atmospheric pressure, solutions saturated with oxygen, and solutions with oxygen bubbling over the electrode are presented with a review of previous work. Results showed that in all cases the potential is highest at the end of a trial for the acid solution as made up, and lowest for the solution in which oxygen was bubbling. The curve for the oxygen saturated solution lay in an inter-

mediate position. Average values for the e.m.f. at 3,000 seconds after immersion for each trial are given. Reference is made to tests by Brown, Roetheli and Forrest, who tested initial corrosion rates in water of iron and six other metals. For iron, zinc, and aluminum, the rate of reaction was determined by the rate of oxygen diffusion through the solution to the metal surface; while the rates for copper, nickel, tin and silver depended on the reaction rate between the metal and oxygen.

Theory of the Oxidation of Alloys.

A. SMIRNOV, Zhur. Eksper. Teoret. Fizike, **14**, No. ½, 46-59 (1944) (In Russian). J. of the Inst. of Metals & Metall. Abs. **12**, 400 (1945) Dec.

The process of the oxidation of binary alloys at high temperatures is considered in terms of a simplified conception, the basis of which is the relation between the coefficient of diffusion and the oxide content. The protective effect of small additions of low-melting admixtures is discussed.

Electron Microscope Probes

Atomic Nature of Rust. Steel, **118**, No. 3, 78-79 (1946) Jan. 21.

Atomic nature of the oxides that form on metals, known as rust or corrosion, is being investigated at Westinghouse Research Laboratories with the aid of the electron microscope, the electronic diffraction camera, and the vacuum microbalance. As air affects metals differently at various temperatures, experiments are conducted over a wide range, from minus 270° to plus 930° F.

GAS CONDENSATE WELL CORROSION

Formaldehyde as an Inhibitor of Corrosion Caused by Hydrogen Sulfide. P. L. MUNAL AND T. H. DUNN, Stanolind Oil and Gas Co., Petroleum Technology **9**, Tech. Publication No. 1970 (1946) Jan.

Laboratory investigation of the problem of combating corrosion of subsurface oil-well equipment, caused by brines containing hydrogen sulfide, showed that addition of certain chemicals greatly reduced the corrosion. These chemicals were carbon monoxide, aldehydes, and certain cyanides such as potassium cyanide. Careful study indicated that formaldehyde was most adaptable to field trial and showed very good promise. Field tests proved its effectiveness in reducing corrosion of valves, tubing and sucker rods. It was also discovered that stray currents were causing great damage on some wells. These were eliminated by installing insulating flanges.

Reports on the Chemical World Today — Formaldehyde vs. Sulfide Corrosion. Ind. & Eng'g Chem., Ind. Ed. **38**, No. 1, 10, 14 (1946) Jan. 16.

The use of formaldehyde as an inhibitor of sulfide corrosion is announced by the Stanolind Oil & Gas Co. Remedies and attempts to prevent sulfide corrosion, such as the use of special alloys, paints, galvanized equipment, and treatment of wells with alkalis, had not proved satisfactory. Nickel alloy pump rods resist corrosion, but their cost is high, and they induce galvanic corrosion in the steel well tubing. Field tests started more than a year ago showed that formaldehyde was al-

most 100 percent effective in preventing this type of corrosion on new equipment, when other causes were excluded. Where corrosion and pitting had started or oxygen was present, formaldehyde was less effective. In practice, a 40 percent solution is dripped into the annulus between casing and tubing. The chemical reaction is analyzed.

GENERAL CORROSION

The Corrosion of Metals. Inst. of Physics, Imperial College of Science and Technology, London (7/7/45). *Nature* **156**, 435 (1945) Oct. 13.

W. H. J. Vernon reviewed the following: (1), electrolytic corrosion, (a), hydrogen-evolution type, (b), oxygen-absorption; (2), atmospheric corrosion, (a), metal-liquid reactions, (b), metal-gas reactions. There is probably a critical humidity for each metal, below which corrosion is of the metal-gas type, and above which it is of the metal-liquid type. J. C. Hudson discussed the influence of composition on the rate of corrosion of iron and steel. When completely immersed in sea-water, mild steel has been found to corrode at rates of 4.5 mils/year; the rate in clay soils is 1.5 mils/year. The addition of 0.5 percent copper and 1.0 percent chromium doubles or trebles the corrosion resistance of the steel. Protective coatings suitable for iron and steel immersed in sea-water are paints in a modified phenol formaldehyde standard oil admixture with white lead, aluminum and other pigments. A multiple recording apparatus devised by P. T. Gilbert and A. B. Winterbottom, which records the variation with time of the electrode potential of corroding metal

couples, is described. The unit can be used for simultaneous tests on four complete couples, and takes 21 individual records per cycle, including the potential difference between each member of each couple and reference electrode.

INHIBITORS

Inhibitors in Turbine Oils Reduce Oxidation and Prevent Rust. E. W. GARDINER, Calif. Research Corp. Power **90**, 87 (1946) March.

Turbine oils should have, in addition to proper viscosity and high flashpoint, these other properties: oxidation stability, rust prevention, ability to separate from water, non-corrosiveness to bearing metals, and low tendency to foam. This article considers oxidation stability and rust prevention. The A.S.T.M. tests are discussed. Results on conventional and inhibited oils are shown in charts and photographs. The need for oxidation and rust inhibitors is shown.

METAL FAILURE

Diffusion in R301 Alloy and Its Effect on the Corrosion Resistance—TP 1940. L. F. MONDOLFO (Reynolds Metals Co.), Paper for A.I.M.E. Metals Tech., **12**, No. 8, 1-13 (1945) Dec.

In clad aluminum alloys, where the core contains copper and the cladding does not, as in R301, at elevated temperatures the copper tends to diffuse from the core through the cladding. The present investigation studies the diffusion features of R301. Corrosion tests were also given, by immersing the specimens, aged six hours at 350° F., in a solution of sodium chloride and hydro-

gen peroxide for 24 hours. Type of corrosion only was studied. This is determined, in the aged state, by percentage of copper at the surface. When copper at surface is below 0.60, corrosion is of the pitting type. When it is above 0.90, corrosion is intergranular. Thickness of cladding, soaking temperature, and soaking time affect two types of corrosion only, as a consequence of their effect on percentage of copper at the surface. Diffusion data are tabulated, etched specimens show diffusion boundaries, and potential measurements are given.

Report of Committee A-5 on Corrosion of Iron and Steel. A.S.T.M., 1945, Preprint 4, 21pp.

Reports from Committee A-5 subcommittees, engaged in making periodic inspections of black sheet, galvanized sheet, and wire and wire products exposed to outdoor weathering, are presented. Data are given on specimens of copper-bearing and non-copper-bearing corrugated black sheets exposed at Annapolis since 1916, and on wire and wire products of copper-coated, lead-coated, and non-coated corrosion-resistant wire (18-8 and chromium stainless) after eight years exposure at each of 11 locations. Loss of tensile strength after various periods of exposure and progressive development of rust on zinc-coated, unfabricated wire, are also given.

Correspondence—Failure of Spring Loops by Stress—Corrosion. R. PARSONS, Ohio Brass Co., Metal Progress, 48, No. 4, 1310-1311 (1945) Dec.

"Pre-loaded" springs (coils wound

tight against each other), of heat-treated SAE 1065 spring wire, requiring pickling and Parkerizing as final finish, broke by a corroded transverse crack on inner surface of coil after Parkerizing. Tests were made, and it was concluded that cracks were caused by stress corrosion in the pickling or Parkerizing vats. Painting of springs solved the problem. Without the Magnaflux test, it might have been concluded that 100 percent pre-flexing and elimination of the pickle produced a satisfactory article; but the shallow cracks likely to be present would have made an inferior device, with lowered fatigue resistance. Stress analysis, presented in April *Metal Progress* by Brewer and Ihren, completed the picture.

Stress Corrosion—The Effect of Added Elements on Aluminum-Magnesium-Zinc Alloys. H. G. PETRI, G. SIEBEL, AND H. BOSSKUHLER, Aluminum, Metal Ind., 67, No. 15, 233 (1945) Oct. 12.

Aluminum-magnesium-zinc alloys have a tendency toward stress-corrosion, which increases with increasing sum of magnesium-zinc, in which a change in the ratio zinc:magnesium toward higher zinc contents exerts a particularly bad influence. Since the alloy, 4.5 percent zinc and 3.5 percent magnesium, lies outside the dangerous range of concentration, the effect of other additions on stress-corrosion was investigated. Effect of cerium, copper, copper with manganese, chromium-copper-manganese, chromium, and chromium-vanadium, and other combinations was studied. The best stress-corrosion resistance was found to be obtainable by combina-

tions of chromium-copper-manganese, chromium-copper-manganese-vanadium, or chromium-copper-manganese-titanium. Most favorable composition was: 0.1-0.4 percent chromium, 0.1-0.6 percent copper, 0.1-0.5 percent manganese, to 0.1 percent titanium and to 0.1 percent vanadium. Mechanical properties resulting from the various additions are also discussed.

Investigations on Wrought Aluminum-Zinc-Magnesium Alloys. III.—Tensile Properties and Stress-Corrosion in the Hot Age-Harden Condition. A. MUHLENBRUCH AND H. J. SEEMANN, *Luftfahrtforsch.*, **19**, No. 10-12, 337-343 (1943), *J. of the Inst. of Metals and Metall. Abs.*, **12**, 315-316 (1945) Oct.

The effects of various annealing treatments on the tensile strength, elongation, and stress-corrosion of two aluminum-zinc-magnesium alloys (zinc 6 and 4, magnesium 2) was investigated. The tests were carried out on standard 1-mm. thick cold-rolled sheets, and on specimens of such sheet annealed (homogenized) for 20 minutes at 440° C. in a salt bath, and subsequently quenched in water (W.Q.), or air-cooled (A.C.). Annealing took place either immediately after solution treatment at 20.200° C. in steps of 20° for five hours, one, five, 14, and 25 days; or for 14 or 28 days at 100° C. for the same periods, after aging at room temperature. Considerable increases in tensile strength and yield strength were obtained by annealing. Optimum values obtained are shown. Stress-corrosion was investigated by immersing samples in three percent sodium chloride solution, within 24 hours of annealing,

five minutes immersion alternating with 25 minutes drying. The resistance to stress-corrosion, which the zinc 4, magnesium 2 alloy possesses in the cold age-hardened state, as well as in after water-quenching, is lost on annealing up to about 100° C., and reappears only at higher temperatures. Cold deformation up to 10 percent does not materially affect the stress-corrosion of either alloy.

Cavitation in Centrifugal Pumps. A. H. STEPANOFF, Ingersoll-Rand Co., Paper before A.S.M.E., Semi-Ann. Mtg., June, 1944. Trans. of the A.S.M.E., **67**, No. 7, 539-552 (1945) Oct.

The present state of information on cavitation is presented as it applies to centrifugal pumps, with a method for determining cavitation conditions from velocity considerations. The discussion is illustrated by curves and diagrams. The model test laws as applied to cavitation are deduced, with their limitations. The presence of gases in liquids does not affect the behavior of pumps as to cavitation, except that vaporization starts at a higher absolute pressure, due to the law of partial pressures. Drop in head capacity may appear earlier on account of liberation of gases of reduced pressure, and the water-hammer effect of collapsing vapor bubbles is cushioned. Penetration of metals by water under repeated stresses furnishes a logical explanation for the origin of local destructive high pressures found during cavitation, and also for the cases of metal failure from fatigue in presence of liquids. Thirty-two references.

Stress-Corrosion Phenomena in Iron Alloys. H. BENNEK, Korrosion und Metallschutz, **20**, April, 1944, 133-141. Mond Gen. Refer. Sheet, Ser. No. 463, 19 (1946) Jan. 5.

Discussion of stress-corrosion phenomenon and the form it takes in iron alloys, as related to structure of the material, corroding medium, degree of stress, and the characteristics of the steel. The data presented, on austenitic, ferritic-pearlitic, and martensitic steels, lead to the conclusion that intercrystalline stress-corrosion are attributable to the same basic cause. Bibliography.

Fretting Corrosion, a Chemical-Mechanical Phenomenon. K. DIES, Z. des V.D.I., **87**, No. 29/30, 475-476 (1943) July Engrs.' Dig., Am. Ed., **2**, No. 1, 14 (1945) Jan.

A simple apparatus for producing fretting oxides for chemical analysis, and to examine their resistance to friction, is described. Test specimens of various types of steel, tin, zinc, copper, light alloys, and a plastic material ("T3") were used. Wear debris was chemically analyzed. A considerable amount of oxygen and varying amounts of nitrogen (mainly as nitrides of iron, chromium or aluminum) were found in wear debris. The experiments did not support the belief that rate of wear increases with hardness of test specimens. With mild or nitrided steel rubbing against chromium steel, the same rate of wear was observed; and a comparatively soft austenitic chromium-nickel steel, or aluminum, attacked hardened steel more than nitrided steel did. Condition of wear is partly dependent on nature of fretting oxides produced. These also can act as further producers of wear, or

can protect against it, according to whether they stick to the surface, or are loose. Wear products obtained with stainless steel rubbing against chromium steel show a very strong abrasive character; and it can be assumed that the chromium nitrides, which are present in small quantities, and perhaps also the hard chromium-nickel-particles, were responsible for the high rate of wear. Influence of lubrication is discussed.

Cavitation in Hydraulic Structures—A Symposium. A.S.E.E. Symposium. Proceedings Am. Soc. of Civil Engrs., **71**, No. 7, 999-1068 (1945) Sept.

Papers in this symposium summarize facts and theories regarding cavitation and describe practical experiences. They include:

Nature of Cavitation. J. K. Venard.

Experiences of the Corps of Engineers. J. C. Harrold.

Experiences of the Bureau of Reclamation. J. E. Warnock.

Experiences of the Tennessee Valley Authority. G. H. Hickox.

Pitting of steel repair plates in the spillway gate slots at the Bonneville Dam occurred. If this becomes general, it will be necessary to use cavitation-resisting alloy steel. Highest gray iron conduit liners of the Shoshone Dam and Norris Dam are mentioned. Some pitting occurred with the former. A bibliography collected by the authors gives 44 references on cavitation.

On the Influence of the Primary Structure on the Corrosion-Resistance of Pure Aluminum. W. HELLING AND E. HAHN, Aluminum, **26**, No. 2/3, 32-35 (1944). J. of the Inst. of

Metals & Metall. Abs., **12**, 398 (1945) Dec.

Ingots were made from pure aluminum under various casting conditions and mold-cooling rates and pressed into strips. Discs cut from these strips were drawn into cans similar to those used for food preservation. The corrosion behavior of the ingots, strips, and final cans was examined, using various corrosive media, and correlated with the macro and microstructures of the specimens. It was concluded that the corrosion-resistance was strongly influenced by the structure of the original casting, being better the finer the distribution of intermetallic compounds in the original structure.

The Corrosion Effect in Water-Hammer Tests. M. VATER AND M. HENN, Korrosion und Metallschutz, **20**, 185-189 (1944) June. Mond Gen. Refer. Sheet, Ser. No. 463, five, 19 (1946) Jan. 5.

Report of tests with "special" cast iron, three types of cast carbon steel, including eutectoid steel, cast 13 percent chromium steel, and aluminum alloy. Results show that the corrosive influence is similar to that operative under alternating corrosion-fatigue conditions. The greater the frequency of water-impact, the less is the corrosion effect. The data indicate that wear tests (frequently used as a rapid method of assessing susceptibility to deterioration under water-hammer) are insufficient to supply valid data on probable service behavior, since the corrosion effect is not sufficiently provided for in such tests.

Correlation of Mechanical Properties and Corrosion Resistance of 24S-Type Aluminum Alloys as Affected by High-Temperature Precipitation—TP 1934. W. D. ROBERTSON (Aluminum Labs. Ltd., Canada. Paper for A.I.M.E. Metals Tech., **12**, No. 7, 1-12 (1945) Oct.

By using an equation, given for expressing effect of precipitation time and temperature on initial change and ultimate maximum mechanical properties and initial maximum and ultimate susceptibility to intercrystalline corrosion, a method for summarizing large volume data and facilitating choice of optimum precipitation time and temperature to obtain desired properties is provided. Graphs show this correlation for 24S-T. Change in character and intensity of corrosive attack after precipitation treatment at 175° C. is also shown. The appearance of grain-boundary precipitation results in intercrystalline corrosion, which increases to a maximum at the time when general precipitation begins, after which the degree of corrosion decreases until it attains a constant low value, indicating that the reaction of general precipitation is complete. The simultaneous occurrence of maximum t.s. and yls. is obtained after treatment for two hours at 210° C.

The Permanent Bending Strength of Some Aluminum Alloys as Affected by Corrosion, in Comparison with Cast Iron and Red Brass. R. STERNER - RAINIER AND W. JUNG-KONIG, Korrosion und Metallschutz, **18**, 1942, 337-343. Chem. Abs., **40**, 304 (1946) Jan. 20.

Although magnesium-aluminum alloys are supposed to be more cor-

rosion resistant than other aluminum alloys, corrosion fatigue tests by methods previously described fail to indicate such superiority. Aluminum-silicon alloys were at least as good. Although the standard values of corrosion fatigue for the tested aluminum alloys agree approximately with those for aluminum bronze, the corrosion resistance of these alloys is greater than that of either aluminum alloys under the given conditions. The corrosion fatigue values for the cast and cold-formed aluminum alloys show no special differences. A considerable improvement is obtained by suitable Elokal treatment. Results obtained in practice appear to contradict laboratory results, presumably because of the relatively short time of application of mechanical stress, as compared with time of exposure to the corroding medium.

Pipe Protection in Sydney. T. W. HUGHES, Gas Journal—247—348 (1946) Feb. 27.

"For the past eight years we have used a Portland cement sand mixture (1:3) one inch thick on the pipes, and on occasion they have been unearthed, because building alterations or for an enlargement on the service, and have been found to be in excellent condition, even in wet clay soils where unprotected pipes failed in less than two years.

"Mention is made by Mr. Escreet (Gas J., June 27, 1945) of wooden formers. For some time we used asbestos-cement troughing, but in recent years we have used cardboard in three-foot lengths, three inches wide for one-inch and one and one-fourth-inch diameter pipes, and four inches wide for one and one-half and

two-inch diameter pipes. This is creased longitudinally to form three equal sections to facilitate bending into the form of an open trough. It is waxed to render it waterproof, and to prevent the cardboard from becoming soggy for a sufficient length of time to allow for the initial set of the concrete.

"To prevent the sides bulging due to the weight of the wet concrete, a steel saddle, shown in an accompanying sketch, is placed over the troughing before the mixture is poured in, and then removed when the earth has been placed alongside the cardboard form. This procedure has proved very successful; and this form of troughing is cheaper than wood or asbestos cement, and, of course, is left in the ground."

Measurement of Cathodic Protection Currents in Submarine Pipelines. W. RYLAND HILL, University of Washington, Seattle, The Petroleum Engineer 17, No. 4—168, 170, 172, 174 (1946) March.

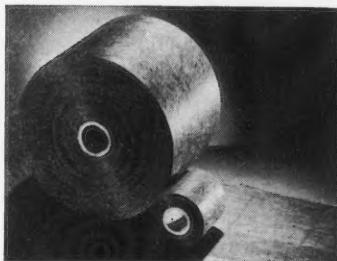
Since loading lines used for loading tankers at sea are especially subject to corrosion and are difficult to replace, cathodic protection is warranted. The cathodic protection system commonly consists of an anode placed some distance from the shore end of the pipeline, a rectifier or other source of d.c., and the necessary connecting cables. The only convenient measurements that can be made on the system are: (1), determination of the current at point A at the shore end of the line; and (2), measurement of the total voltage drop between the sea end of the line B and the shore end A. The voltage drop between A and B can be made by using the telephone laid



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with the pipeline for ship-to-shore communication. These two measurements, together with an accompanying chart, permit a reasonable estimate of the minimum current density at the sea end of the line.

New Corrosion Report on Soil Pipe Issued by Bureau of Standards.
Bureau of Mines, The Iron Age—157, No. 16—152, 154 (1946) April 18.

Estimating an annual national cost of \$200 million in replacement of underground pipelines made unserviceable by corrosive action of soils, the Bureau of Standards has just issued Circular C-450, the result of 25 years of continuous investigation designed to minimize this economic loss. The circular was prepared by Kirk H. Logan, head of the Underground Corrosion Section.

"Soil characteristics and conditions are so complex that it has been found impossible to correlate corrosion with any single soil property," the circular states. "Likewise, no one pipe material or protective coating is the best under all soil conditions.

"The Bureau's studies indicate that ferrous materials in common use do not differ greatly in resistance to corrosion. However, ferrous alloys containing rather high percentages of nickel and chromium are definitely superior. Copper and alloys with a high copper content corrode much less and more uniformly than ferrous materials. On the other hand, lead is resistant to many soils but pits deeply in some of them.

"Corrosion decreases with time; and any 'corrosion rate' is applicable only to the area of the pipe that was actually tested, and to the period in which measurements were made. For this reason, the life of a pipe

cannot be predicted from loss in weight or depth of a pit as measured during only one period.

"The effectiveness of metallic coatings depends on the soils to which they are exposed," according to the circular. "No one coating was found to be suitable for all soils. Bituminous coatings greatly retard loss of metal, their effectiveness being roughly proportional to their thickness. Unfortunately, very few of these coatings are free from pin holes and other imperfections.

"In this connection," the Bureau states, "important causes of failure are improper application and injuries received while laying the pipe. Better tools and methods have reduced the failures from these causes, but it is still difficult to secure a completely protected pipe. Even after the pipe is in place, the coating may be injured by soil stress and the roots of trees, shrubs and grass.

"The results of tests on a number of promising coatings developed in the laboratory are presented in the publication. Several procedures for testing soils and coatings are also described and corrosion prevention methods compared.

"Cathodic protection is shown to retard or prevent corrosion under most soil conditions. Methods for applying this electric type of protection are briefly described.

"Six appendices give details of test methods and apparatus referred to in the text of the publication.

"Copies of Circular C-450 may be obtained from the Supt. of Documents at \$1.25 ea."

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REFINERY CORROSION

Stainless and Heat Resisting Steels. JOHN L. EWING, Carnegie-Illinois Steel Corp., Petr. Eng., 17, 124 (1946) Feb.

Stainless and heat-resisting steels have a wide range of uses in the petroleum refining industry. Operating efficiency, quality of product, and economy are primary design considerations. Other items necessary to consider are corrosion resistance, structural strength, and safety factors. Corrosion and heat resistances increase as the percent of chromium is increased. Stainless steel bubble caps are gaining in popularity in fractionating columns handling sour products because there is less fouling, less weight and better operation. Bubble trays of stainless steel with careful design can compete with steel or cast iron on an economic basis, because of less weight, less breakage, less fouling, less heat capacity, etc. Stainless steel is also proving practical for making liners, valves, pumps and other miscellaneous refinery operations.

SURFACE TREATMENT

Surface-Conversion Coatings. G. W. JERNSTEDT, Westinghouse Elect. Corp., A.S.T.M., Bull. No. 137, 29-35 (1945) Dec.

Phosphating, blueing, anodic oxidation, chromatizing, and other surface conversion processes are discussed, with characteristics of each. These coatings are relatively thin and non-flexible, and cannot be drawn or bent. Resistance to salt spray tests, and suitability of processes to various metals are discussed and tabulated.

Corrosion Protection. T. S. BUGG, Mechanical World, 118, 493 (1945) Nov. 2.

A collection of information on present-day processes and methods. Under the protection of iron and steel, various paints, galvanizing, parkerizing, bonderizing, sherardizing, and metallizing processes are discussed. It is pointed out that thorough cleaning is the primary operation in all of these coatings and treatments. The principal applications of the metals after treatment are discussed. High silicon and high chrome alloy irons are mentioned briefly. The anodizing treatment of aluminum is discussed in some detail.

WATER CORROSION

Developments in Corrosion Studies and Corrosion Control. H. M. OLSEN, Ohio Salt Co., Iron and Steel Engineer 23, 80 (1946) Jan.

Corrosion studies are divided into three groups: (1), corrosion due to atmospheric conditions; (2), corrosion due to water conditions; and (3), corrosion due to soil conditions. These groups are reviewed with reference to causes and prevention of corrosion, with major emphasis on group 2. The author states that the most interesting developments in controlling corrosion have been application of sodium hexametaphosphate, cathodic protection, silica gel and the combination of phosphates and sodium silicates. A bibliography of 100 articles is included. Many of these articles are abstracted in above paper.

Electrochemical Measurements for Corrosion Studies. G. T. GILBERT (Brit. Non-Ferrous Metals Res.



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Assoc., London), *J. Sci. Inst.*—22, 235-7 (1945). CA 40, 1772 8, April 10, 1946.

The behavior of pairs of coupled metals in tap water was followed to establish the relationship between them as they corroded under various conditions. The temperature was varied up to 85°, and the concentration of dissolved oxygen and carbon dioxide was varied. The apparatus used to hold the metal specimens and the reference electrodes is shown. The silver-silver chloride reference electrode was chosen for this work. The electrode potentials of zinc and iron specimens were followed in this way. The potentials and corrosion currents from four couples of corroding metals were simultaneously and continuously recorded. The four cells were heated to 85° in an oil thermostat for a period of eight hours each day, and allowed to cool overnight. If the corrosion taking place is entirely or largely electrochemical, the zinc and iron are corroding in contact and an unknown factor is generally introduced. Local cathodes on the anode and local anodes on the cathode, will cause an increase in the corrosion over that due to the passage of current between anodic and cathodic electrodes. With a single metal, these local elements will cause most, or all of the corrosion, but when an electropositive and an electronega-

tive metal are coupled, the effect may be only a secondary one.

Cold Water Vacuum Daeeration.
SHEPPARD T. POWELL, Consultant, Water and Sewage Works 93, 93 (1946) March.

History of deaeration, applicability, selection of design, secondary chemical treatment, costs and efficiencies are discussed. Charts and diagrams illustrate construction and operation.

Air Conditioning Systems and Their Chemical Treatment. WILLIAM A. TANZOLA, W. H. AND L. D. BETZ, Southern Power and Industry 64, 60 (1946) Feb.

Control of corrosion, scale formation and organic growths are discussed as factors in reducing maintenance costs. Phosphates, chromates, nitrites and nitrogenous organic materials, together with pH adjustment is recommended for control of corrosion. Potassium permanganate, chromates, chlorinated phenols, benzylphenol, and chlorine are suggested for control of organic growth. The prevention of scale formation in the condenser water involves the use of surface active agents in conjunction with controlled blowdown. Such chemicals in use are phosphates, tannins, lignins, starches and combinations of these.

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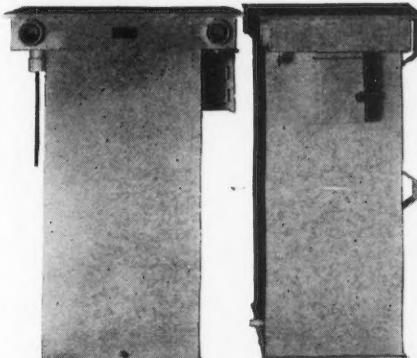
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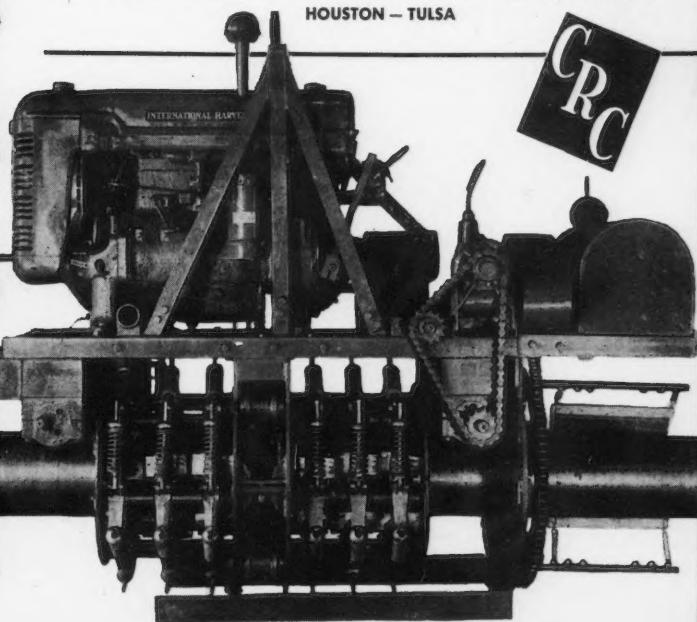
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The new CRC Model "C" Pipe Cleaning Machine is engineered and field-designed to clean more pipe faster for a longer period of time than any other available machine. Write for details.

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